ANNUAL LETTER

1989-90

INSTITUTE OF TROPICAL FORESTRY

RIO PIEDRAS, PUERTO RICO

SOUTHERN FOREST EXPERIMENT STATION

USDA FOREST SERVICE

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Southern Forest Experiment Station
Institute of Tropical Forestry
Call Box 25000
Río Piedras, Puerto Rico 00928-2500
June 1991

Dear friends:

This letter covers the period from October 1, 1989 to September 31, 1990, a period of time that included the passage of Hurricane Hugo on September 18, over the Luquillo Experimental Forest. Hurricane Hugo was a class V hurricane, one that has a return frequency of 60 years. Needless to say that the programs of the Institute were greatly affected by this event. Tables 1-3 at the end of he English version of the letter summarize all Institute activities for this time period.

Because of the hurricane, we had to close studies, open new ones, replace damaged equipment, reconstruct facilities, and suffer delays in many of our publications. Two publications that suffered delays were our anniversary symposium volume and a special publication dealing with the history of the Institute. As I write this letter however, our programs are once again reaching a normal cruising speed, and I hope that these publications will be completed soon. The next Annual Letter will cover in more detail the effects that Hurricane Hugo had in our programs, as well as some of the findings of the new research conducted to assess the role of disturbance on tropical ecosystems.

I look forward to sharing with all of you the results of these and other new Institute initiatives in tropical forestry research. Please keep in touch and share with us the results of your own work in the tropics.

Sincerely,

ARIEL E. LUGO
Director and Project Leader

Estación Experimental de los Bosques del Sur
Instituto de Dasonomía Tropical
Call Box 25000
Río Piedras, Puerto Rico 00928-2500
junio 1991

Estimados Amigos:

Esta carta cubre el período de tiempo entre el primero de octubre del 1989 y el 31 de septiembre del 1990. El 18 de septiembre del 1989 pasa sobre el Bosque Experimental de Luquillo el Huracán Hugo, un huracán de categoría V y frequencia de retorno de 60 años. Este evento impactó todas las actividades del Instituto durante este período de tiempo. Las Tablas 1-3 al final de la versión en inglés de la presente, resumen nuestras actividades principales.

Debido al huracán tuvimos que cerrar algunos estudios, comenzar otros, reemplazar equipo destruido por el viento, reconstruir facilidades, y observar como se retrasaron algunas publicaciones. Dos publicaciones que se retrasaron fueron el libro basado en el simposio del aniversario, y una publicación especial sobre la historia del Instituto. Sin embargo, al momento de escribir esta carta ya los programas del Instituto vuelven a su ritmo normal y esperamos tener estas publicaciones listas este año. La próxima carta anual cubrirá en detalle los efectos del Huracán Hugo en nuestros programas y los resultados de las investigaciones que comenzamos para estudiar el efecto de disturbios sobre ecosistemas tropicales.

Espero poder compartir con ustedes los resultados de estos esfuerzos y de otras iniciativas de investigación que estamos tomando en el Instituto. Por favor mantengan la comunicación con nosotros y compartan los resultados de sus investigaciones tropicales. ¡Apreciamos mucho su colaboración!

Cordialmente,

Ariel E Lugo

ARIEL E. LUGO

Director y Líder de Proyecto

INSTITUTE OF TROPICAL FORESTRY ANNUAL LETTER

1991

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PLANTATION FORESTRY RESEARCH

John K. Francis
Research Forester

The genus *Eucalyptus,* which contains more than 500 species, originated in Australia except for one that comes from islands to the north of the continent. The eucalypts are valued as plantation species because of their useful wood, amazingly fast growth, drought resistance, and low nutrient requirements. More than 30 species have been tested in Puerto Rico. Although most died within the first few years, a few species with impressive performance have emerged.

Eucalyptus robusta has grown in Puerto Rico for 60 years and has given the most consistent performance of the eucalypts tested. It does best in moist and wet habitats with deep acid soils. Hundreds of hectares of plantation can be found in the Toro Negro, Carite, and Monte Guilarte Commonwealth forests. "Robusta" will produce 10 to 30 m^3/ha of wood annually depending on site quality and age of the plantation. Unfortunately, the wood is hard and seasons very poorly. Round and sawn fence posts are the main products produced from "robusta" in Puerto Rico.

Eucalyptus deglupta is the only non-Australian eucalypt. "Deglupta" grows impressively in low elevation, habitat with fertile soils. Young plantations in Puerto Rico have yielded 10 to 30 m^3/ha annually. Probably, more rapid growth is possible on medium-textured alluvial soils. Three 10-year-old open-grown individuals on the Institute grounds have grown an average of 6 cm in diameter per year. "Deglupta" has a beautiful and very workable wood that has not yet been harvested in Puerto Rico. This tree is planted as an ornamental for its striking multicolored bark. Two recent ITF publications describe the species (Francis 1988, Lugo and Francis 1990).

Other species that have had acceptable survival and shown good growth in rotation-length tests are *E. grandis, E. citriadora, E. resinifera, E. torelliana, E. acmenoides, E. urophylla*, and two hybrids. Whether planting eucalypts on a significant scale for wood production will ever be justified in Puerto Rico is open to question. It is certain, however, that on acceptable sites, some eucalypts can be very productive when planted in Puerto Rico.

Literature Cited

Francis, J.K. 1988. *Eucalyptus deglupta* Blume Kamarere. Research Note SO-ITF-SM-16. New Orleans, LA. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 5 p.

Lugo, A.E. and J.K. Francis, 1990. A comparison of 10 provenances of *Eucalyptus deglupta* and *E. urophylla* in Puerto Rico: growth and survival over 15 years. Commonwealth Forestry Review 69(2):157-171.

TROPICAL SILVICS MANUAL

John K. Francis
Research Forester

A project for the tropics paralleling the U.S. Silvics Manual was begun several years ago and has progressed steadily since them. The project consist of short monographs on important tree species native to, or planted in, Puerto Rico. Monographs contain information on life history, growth characteristics, management methods, and uses. The information has been gleaned from the literature and from data collected by the individual authors. In most cases, distribution maps and photographs of the trees are included. They are published in English in 3-hole format to be assembled in binders as they appear. To date, entries for 34 species have been printed and about 25 more are being prepared. Silvical descriptions for another 20 tropical species are in the 1991 U.S. Silvics Manual (Agricultural Handbook 654). Ultimately, we will combine all these descriptions into hard cover volumes—both in English and Spanish. Listed in the following table are species, authors, and publication numbers of the "Tropical Silvics Manual" entries published so far. Copies can be obtained from the Institute of Tropical Forestry.

Species	Authors	Publication Number
Anthocephalus chinensis	A.E. Lugo and J. Figueroa	SO-ITF-SM-01
Rhizophora mangle	J.A. Jimenez	SO-ITF-SM-02
Laguncularia racemosa	J.A. Jimenez	SO-ITF-SM-03
Avicennia germinans	J.A. Jimenez and A.E. Lugo	SO-ITF-SM-04
Khaya senegalensis	A. Bokkestijn and J.K. Francis	SO-ITF-SM-05
Albiziaprocera	J.A. Parrotta	SO-ITF-SM-06
Albizia lebbek	J.A. Parrotta	SO-ITF-SM-07
Maesopsiseminii	J.K. Francis	SO-ITF-SM-08
Khaya nyasica	J.K. Francis and A. Bokkestijn	SO-ITF-SM-09
Agathis robusta	J.K. Francis	SO-ITF-SM-10
Araucaria heterophylla	J.K. Francis	SO-ITF-SM-11
Terminalia ivorensis	J.K. Francis	SO-ITF-SM-12
Hernandia sonora	J.K. Francis	SO-ITF-SM-13
Hibiscus elatus	P.L. Weaver and J.K. Francis	SO-ITF-SM-14
Enterolobium cyclocarpum	J.K. Francis	SO-ITF-SM-15
Eucalyptus deglupta	J.K. Francis	SO-ITF-SM-16
Guarea guidonia	P.L. Weaver	SO-ITF-SM-17
Bucida buceras	J.K. Francis	SO-ITF-SM-18
Pterocarpus macrocarpus	J.K. Francis	SO-ITF-SM-19
Andira inermis	P.L. Weaver	SO-ITF-SM-20
Thespesia grandiflora	J.K. Francis	SO-ITF-SM-21
Mammea americana	J.K. Francis	SO-ITF-SM-22
Terminalia catappa	J.K. Francis	SO-ITF-SM-23

Species	Authors	Publication Number
Dalbergia sissoo	J.A. Parrotta	SO-ITF-SM-24
Tabebuia donell-smithii	J.K. Francis	SO-ITF-SM-25
Syzygium jambos	J.K. Francis	SO-ITF-SM-26
Hymenaea courbaril	J.K. Francis	SO-ITF-SM-27
Fraxinus uhdei	J.K.Francis	SO-ITF-SM-28
Ceiba pentandra	J.D. Chinea	SO-ITF-SM-29
Tamarindus indica	J.A. Parrotta	SO-ITF-SM-30
Paraserianthes falcataria	J.A. Parrotta	SO-ITF-SM-31
Spathodea campanulata	J.K. Francis	SO-ITF-SM-32
Senna siamea	J.A. Parrotta and J.K. Francis	SO-ITF-SM-33
Citharexylum fruticosum	J.K. Francis	SO-ITF-SM-34

FORESTRY RESEARCH AND MANAGEMENT

Peter L. Weaver
Research Forester

Natural Forests

The tabonuco forest (lower montane rain forest *sensu* Beard; subtropical wet or rain forest *sensu* Holdridge) is found between 150 and 600 m in elevation in the Luquillo Experimental Forest; the colorado forest (montane rain forest *sensu* Beard; lower montane wet or rain forest *sensu* Holdridge) is situated between 600 and 900 m in elevation; and the dwarf forest (dwarf forest *sensu* Beard; atmospheric association in the lower montane wet or rain forest *sensu* Holdridge) is situated between 900 m and the 1050 m summits of the Luquillo Mountains. The colorado and dwarf forests are cloud forests. Studies of forest dynamics initiated in the early 1980's demonstrated that tropical montane cloud forests are low in productivity and slow to recover from disturbance.

Net primary production in the colorado forest was estimated at 7.60 Mg/ha.yr (Weaver and Murphy 1990) by summing litterfall (6.80 Mg/ha.yr), aboveground biomass accrual (0.59 Mg/ha.yr) and herbivory (0.21 Mg/ha.yr). The total leaf area index (trees, epiphytes, and ground vegetation) was about 5 m^2/m^2 and the aboveground woody volume and biomass, 220 m^3/ha and 130 Mg/ha, respectively. Standing herbivory was estimated at 5.1 percent and the herbivory rate at 4.0 percent/yr. The mean standing crop of litter was 6.0 Mg/ha with a turnover rate of 0.78 times per year.

The structural features and dynamics of the tabonuco, colorado, and dwarf forests were compared over a 600-m gradient. Of the structural features studied, the number of trees per hectare, basal area, and soil organic matter increased with elevation. In contrast, the specific leaf area, canopy height, range of tree diameters, forest volume and biomass, leaf area index, and species richness declined. Of the dynamic features studied, ingrowth and mortality of trees, tree growth (diameter, volume, and biomass growth), litterfall, loose litter, standing herbivory and herbivory rates, litter turnover, and aboveground woody net primary production all declined with an increase in elevation.

On December 16, 1968, a transport plane departed from Roosevelt Roads Navy Base and crashed in the dwarf forest near the East Peak Radar Dome. Regeneration on the crash site during the first six years was mainly by ferns and grasses. Another survey was conducted 18 years later and 23 tree species were recorded (Weaver 1990). Of the nearly 1200 arborescent stems that were recorded, three-quarters were elfin forest primary species. Total aboveground biomass averaged 776 g/m^2 and was classified thus: 30 percent arborescent dicots; 13 percent palms; 31 percent ferns, and 26 percent grasses and herbs. Total aboveground biomass recovery after 18 years appeared linear, and, at the observed rate, would require nearly two centuries for the site to return to its original biomass.

Line Planting Proposal

Line planting, sometimes called conversion line planting, is a reforestation technique that has been used with varying success in the tropics to improve the productive potential of degraded secondary forests. Parallel lines about 3 m in width are spaced 11 m apart and planted with

seedlings spaced at about 2.5 m within the cleared lines (about 365 seedlings per hectare). Fast-growing, high value, tropical timber species are then interplanted in the secondary forests. After 20 years or so, with proper tending, a closed stand is produced.

Beginning in the mid-1960's, Institute scientists experimented with line planted mahogany in the Luquillo Experimental Forest. To date, the technique has yielded satisfactory results, and based on that success, a technology transfer plan to promote line planting was developed. Tentatively, Guatemala, the Dominican Republic, and Grenada were selected to cooperate with Puerto Rico in the development of line planted mahogany. The technology transfer plan, approved in July 1990, involves cooperative planning, site selection, nursery production, and outplanting. Potential cooperators within the respective countries have been identified, and regeneration sites have been tentatively selected. The international nature of the proposed plan calls for close cooperation among the cooperating entities.

Literature Cited

Weaver, P.L. 1990. Succession in the elfin woodland of the Luquillo Mountains of Puerto Rico. Biotropica 22(1):83-89.

Weaver, P.L. and P.G. Murphy. 1990. Forest structure and productivity in Puerto Rico's Luquillo Mountains. Biotropica 22(1): 69-82.

Weaver, P.L., G. Zapeda, A. Rodríguez, D. Sims, J. Bauer, D. Jiménez, R. Lea, D. Mengel, and B. Bayle. 1990. Technology transfer plan: line planting. USDA Forest Service, Southern Forest Experiment Station and Southern Region. 19 p.

ECOLOGICAL STUDIES

Ariel E. Lugo
Ecologist

In recent years I collaborated with four colleagues and together published reports on tropical secondary forests (Brown and Lugo 1990a), Caribbean wetlands (Lugo and Brown 1988), soil carbon and nitrogen (Brown and Lugo 1990b), plantation biomass production (Lugo, Wang, and Bormann 1990), and methods for estimating stand biomass from volume data (Brown , Gillespie, and Lugo 1989).

Secondary Forests

The literature on tropical secondary forests, defined as those resulting from human disturbance (e.g. logged forests and forest fallows), was reviewed to address questions related to their extent, rates of formation, ecological characteristics, values and uses to humans, and potential for management. Secondary forests are extensive in the tropics, accounting for about 40% of the total forest area and their rates of formation are about 9 million ha per year. Geographical differences in the extent, rates of formation, and types of forest being converted exist.

Secondary forests appear to accumulate woody plant species at a relatively rapid rate but the mechanisms involved are complex and no clear pattern emerged. Compared to mature forests, the structure of secondary forest vegetation is simple, although age, climate and soil type are modifying factors. Biomass accumulates rapidly in secondary forests, up to 100 t ha^{-1} during the first 15 yr or so, depending on past disturbance. Like biomass, high rates of litter production are established relatively quickly, reaching 12-13 Mg/ha.yr by age 12-15 yr. And, in younger secondary forests (<20 yr), litter production is a higher fraction of the net primary productivity than stemwood biomass production. More organic matter is produced and transferred to the soil in younger secondary forests than is stored in above-ground vegetation. The impact of this on soil organic matter is significant and explains why the recovery of organic matter in the soil under secondary forests is relatively fast (50 yrs or so). Nutrients are accumulated rapidly in secondary vegetation, and are subsequently returned by litterfall and decomposition for uptake by roots.

We proposed a model of the gains and losses, yields and costs, and benefits and tradeoffs to people from the current land-use changes occurring in the tropics (Fig. 1). When the conversion of forest lands to secondary forests and agriculture is too fast or land-use stages are skipped, society loses goods and services. To avoid such a loss, we advocate management of tropical forests lands within a landscape perspective, a possibility in the tropics because land tenures and development projects are often large.

Caribbean Wetlands

The area of individual Caribbean island wetlands is generally small, but larger islands have the largest wetland areas. For example, Cuba has a wetland complex that covers 5.0 million ha. Wetland types are extremely diverse in the region and forested wetlands appear to cover more area than non-forested wetlands. The precise area of wetlands in Caribbean islands is not known, but traditional wetland definitions ignore montane wetlands in wet and rain forest environments (>3,500 mm/year) where soils are satured for long time periods and influence

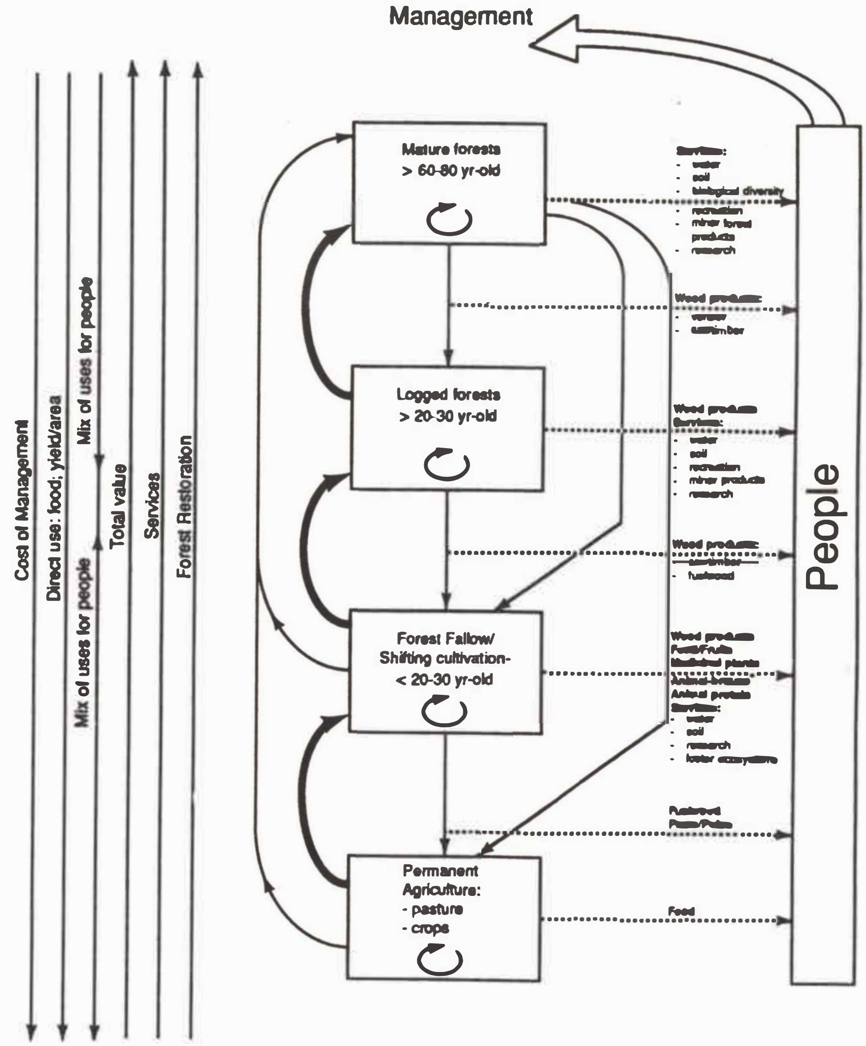

Figure 1. Land-use change in tropical forest lands showing: 1) the conversion of forest lands to other land uses, 2) the products and services (dotted lines) that people derive from the conversion process and the four stages of forest or land use, 3) restoration (arrows on left side of boxes) of forests, and 4) trends in costs and benefits to people from changes in land-use (left side of diagram, trends increase in direction of arrows). Each stage of forst or agricultural land (boxes) can be managed sustainably (shown by circled arrows in boxes), converted to more intensive use (downward arrows), or restored to a more complex forest (upward arrows). Heavy shaded arrows show those restorations most favoured by natural forces. Intensive conversions or restorations may jump over a stage of land-use (boxes) if enough energy is available to overcome costs. Each type of land-use has uniquely important benefits (shown in the trends and listings of products and services) and thus optimal land-use in a landscape requires a mix of all four land-use types.

vegetation structure and function. These types of wetlands were described in detail.

Caribbean island wetlands are characterized by an abundance of flowing water systems, absence of salt marshes and lake fringes, high species richness, abundance of palms, and high rates of primary productivity. Diverse tropical and subtropical climate, topography, geology, and edaphic conditions are believed to be the primary factors that explain the richness and productivity of Caribbean island wetlands. The structural and functional characteristics of riverine, basin, and fringe wetlands in Caribbean islands are compared with world averages and it is concluded that they are different from temperate wetlands (Tables 1 and 2). These difference are due to their climatic environment (tropical, oceanic, and subject to hurricanes), their biotic complexity which in freshwater wetlands is much greater than that of similar temperate wetlands, and small size which makes them vulnerable to piece-meal destruction, reduces buffering potential of large size, reduces margin of error in planning and management, and increases value per unit area of wetland.

Table 1. Ecological characteristics of saltwater wetlands of Caribbean islands. Average values for saltwater wetlands from many areas of the world are also given for comparison (these data are from Lugo et al. 1988). Number of sites used to obtain mean is given in parenthesis.

Ecosystem attribute (units)	Wetland type		
	riverine	basin	fringe
Caribbean wetlands			
Number of species*	2.7 (16)	2.0 (20)	2.2 (25)
Basal area* (m^2/ha)	21.3 (16)	16.0 (20)	22.0 (25)
Tree density* (#/ha)	1874 (16)	3063 (20)	6963 (25)
Tree height* (m)	14.4 (16)	9.7 (20)	10.9 (25)
Litterfall (Mg/ha.yr)	14.5 (1)ξ	7.2 (8)ξ	8.6 (10)†
Global wetlands			
Number of species	2.6 (16)	2.0 (5)	1.7 (32)
Basal area (m^2/ha)	33.2 (16)	18.5 (5)	22.2 (33)
Tree density (#/ha)	2131 (16)	3580 (5)	4005 (33)
Litterfall (Mg/ha.yr)	13.0 (8)	6.6 (8)	7.1 (11)

* Data from Martínez et al. 1979; all trees were measured to a minimum dbh ≥2.5 cm.
† Musa 1968, and Lugo and Musa 1990.
ξ Musa 1986, and Pool et al. 1975
ξ Pool et al. 1975.

Table 2. Ecological characteristics of freshwater forested wetlands of Caribbean islands. Average values for global wetlands are included for comparisons (these data are from Lugo et al. 1988). Number of sites used to obtain mean is given in parenthesis.

Wetland type	No. of species	Basal area (m^2/ha)	Stem density (#/ha)	Average height (m)	Litterfall (Mg/ha.yr)
Riverine					
Floodplain palm[1] forest	27	42.4	3059	17	17.0
Pterocarpus forest[2]					
mountains	13	55.0	1080	32	14.1
coastal	1-2	35.4	3160	22	-
Global wetlands[3]	8.3 (30)	37.8 (32)	1076 (29)	-	5.7 (16)
Basin					
Clusia-Syzygium[4]	11	25.6	3200	20	-
Pterocarpus forests	7	44.6	1680	19	-
	6	54.8	1910	19	11.9
Cloud forest[5]	11	49.1	3671	3.4	3.1
Colorado forest[6]	41	40.0	1858	10	6.8
Palm forests[7]					
400 m	9	17.6	400	19	-
700 m	8	23.8	870	20	-
1000 m	8	43.2	1700	11	-
Global wetlands[3]	6 (17)	39.9 (15)	2834 (14)	-	5.3 (10)

[1] Frangi and Lugo 1985, for trees with dbh ≥1 cm.
[2] Alvarez-López 1989, for trees with dbh ≥2.5 cm.
[3] Lugo et al. 1988.
[4] Figueroa et al. 1984, for trees with dbh ≥2.5 cm.
[5] Weaver et al. 1986, for trees with dbh ≥10 cm.
[6] Weaver et al. 1986, Weaver 1987, for trees with dbh ≥4.1 cm.
[7] Berrios Saez and Pérez Castro 1983, for trees with dbh ≥10 cm.

Soil Carbon an Nitrogen

Soil samples from mature and secondary forests and agricultural sites in three subtropical life zones of Puerto Rico and the US Virgin Islands were collected to determine the effects of forest conversion to agriculture and succession on soil organic carbon (C) and nitrogen (N) contents. Site characteristics that may affect soil C and N (slope, elevation, aspect, and texture) were as uniform as possible. Carbon contents (to 50 cm depth or bedrock) of cultivated sites, as a percent of corresponding mature forests, were lower in the wet (44%) and moist (31%) than in the dry (86%) life zones whereas N contents were relatively high regardless of life zone (60-130% of the mature forests). Conversion of forests to pasture resulted in less soil C and N loss than conversion to crops.

The time for recovery of soil C and N during succession was approximately the same in all three life zones, about 40-50 yr for C about 15-20 yr for N. However, the rate of recovery of soil C was faster in the wet and moist life zone, whereas N appeared to recover faster in the dry life zone. Different rates achieve steady state over the same time interval because the quantity at steady state varies with life zone. Those that have a slow rate, have lower end-quantities than the ones that recover at fast rates. Evidence for loss of soil C during cultivation and gain during succession to soil depths of 50-100 cm was presented.

Plantation Biomass Production

Trees of *Casuarina equisetifolia, Albizia procera, Eucalyptus robusta*, and two varieties of *Leucaena leucocephala* (an exotic and a native) were grown for maximum biomass production under the same climatic (1102 mm mean annual rainfall and 25° C mean annual air temperature) and edaphic conditions in the Lajas Valley of Puerto Rico (lat. 18° N., long. 67° W.). Management was intensive during early growth and establishment phases. Rates of large-branch/stem production (diameter > 2.5 cm) at age 5.5 years were 27.8, 20.4, 10.1, 7.7, and 5.5 Mg/ha.yr for *Casuarina, Albizia, Eucalyptus*, exotic *Leucaena*, and native *Leucaena*, respectively. Stemwood biomass production of 40 tropical tree plantations established elsewhere for biomass production averaged 7.9 Mg/ha.yr. Species ranking in terms of total above-ground biomass and litter accumulation followed the same order. At age 5.5 years, the litter accumulation in plantations was (in the same order): 16.2, 10.2, 11.8, 7.0, and 6.5 Mg/ha. Thirty-five natural tropical forest stands averaged 6 Mg/ha. Intensive management on fertile soils increases biomass yield of energy plantations, but not all species respond equally well to such treatments.

Biomass Estimates from Volume Data

A strategy for estimating total aboveground biomass of tropical forests was suggested. We developed regression equations to estimate aboveground biomass of individual trees as a function of diameter at breast height, total height, wood density, and Holdridge life zone (Table 3).

Table 3. Regression equations for estimated total aboveground biomass (Y kg/tree) and total height (H, m) in tropical forests by life zone group[a].

	Life zone	Equation[b]	Sampled size	R^2 (adj)	MSE
[1]	Dry	$Y = 34.4704 - 8.0671 (D) + 0.6589 (D^2)$	32	0.67	0.02208
[2]	Moist	$Y = 38.4908 - 11.7883 (D) + 1.1926 D^2$	168	0.78	0.06181
[3]	Moist	$Y = \exp \{-3.1141 + 0.9719 \ln (D^2H)\}$	168	0.97	0.1161
[4]	Moist	$Y = \exp \{-2.4090 + 0.9522 \ln (D^2HS\}$	94	0.99	0.06079
[5]	Moist	$H + \exp \{1.0710 + 0.5677 \ln D\}$	3824	0.61	0.07495
[6]	Wet	$Y + 13.2579 - 4.8945 (D) + 0.6713 (D^2)$	69	0.90	0.02247
[7]	Wet	$Y = \exp \{-3.3012 + 0.9439 \ln (D^2H)\}$	69	0.90	0.2110
[8]	Wet	$H = \exp \{1.2017 + 0.5627 \ln D\}$	69	0.74	0.4299

[a] The transformed nonlinear models include the adjustment term (MSE/2) along with the intercept, when appropriate.

[b] "Exp" denotes "e to the power of ..." D = dbh in cm, H = total height in m, and S = wood density in Mg/m^3 = g/cm^3.

The regressions were applied to some 5,300 trees from 43 independent sample plots, and 101 stand tables from large-scale forest inventories in four countries, to estimate commercial and total aboveground biomass per unit area by forest type, and to estimate expansion factors defined as the ratio of aboveground to commercial biomass. The quadratic stand diameter (QSD, i.e., the diameter of a tree of average basal area) in a given forest stand influences the magnitude of the expansion factor. Stands of small trees have large expansion factors (up to 6.4), and as QSD increases, the expansion factor decreases to a constant value (about 1.75). For undisturbed forests in moist, moist transition to dry, and dry life zones respectively, the expansion factors for total aboveground biomass were 1.74, 1.95, and 1.57 respectively. For undisturbed, logged, and nonproductive forest categories used by the FAO to report global commercial wood volume data, we estimated expansion factors of 1.75, 1.90, and 2.00 respectively. Applying these factors to FAO data results in a 28 to 47% increase in previous volume-derived estimates of tropical forest biomass (Table 4). However, estimates of tropical forest biomass based on small destructive samples continue to be high relative to estimates based on volume data.

Table 4. Aboveground biomass estimates of closed tropical broadleaf forests based on volumes (areas, volumes, and stemwood biomass are from Brown and Lugo 1984).

Region	Undisturbed	Logged	Nonproductive
Tropical America			
Area (10^6 ha)		452.98	53.5
147.45			
Volume (10^9 m^3)	71.07	6.37	13.21
Stemwood Biomass (10^9 Mg)	43.92	3.94	8.19
Total Biomass (10^9 Mg)	76.86	7.49	16.38
Weighted biomass (Mg/ha)	169.68	139.93	111.09
Tropical Africa			
Area (10^9 ha)	118.18	43.57	52.66
Volume (10^9 m^3)	30.3	8.41	7.35
Stemwood Biomass (10^9 Mg)	17.56	4.87	4.26
Total Biomass (10^9 Mg)	30.73	9.25	8.52
Weighted Biomass (Mg/ha)	260.03	212.37	161.79
Tropical Asia			
Area (10^9 ha)	97.26	94.62	100.08
Volume (10^9 m^3)	20.97	9.7	14.45
Stemwood Biomass (10^9 Mg)	11.93	5.51	8.2
Total Biomass (10^9 Mg)	20.88	10.47	16.48
Weighted Biomass (Mg/ha)	214.66	110.64	164.67

Table 4. (cont'd.).

Region	Undisturbed	Logged	Nonproductive
Total tropics			
Area (10^9 ha)	668.42	191.69	300.19
Volume (10^9 m^3)	122.34	24.48	35.01
Stemwood Biomass (10^9 Mg)	73.41	14.32	20.69
Total Biomass (10^9 Mg)	128.47	27.21	41.38
Weighted Mean Biomass (Mg/ha)	192.2	141.94	137.85
Weighted Mean Biomass without roots (Mg/ha)[a]	149.6	101.7	93.8

[a] Assuming a root to shoot ratio of 0.16.

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WILDLIFE RESEARCH

Joseph M. Wunderle, Jr.
Research Wildlife Biologist

During the 1990 fiscal year a new project was initiated, two on-going projects were continued, and a short environmental assessment was completed, all of which are summarized below.

The Effect of Hurricane Hugo On Bird Populations In Puerto Rican Rainforest

Hurricane Hugo caused substantial damage to the canopy and understory of the tabonuco forest of the Luquillo Experimental Forest. Two weeks after the hurricane, total net capture rates of birds were higher than previous baseline studies - due to increased captures of canopy species, which were previously rare in the forest understory. Nectarivores were the only species which showed either no change or actually decreased in the first netting session. However, after several months some canopy and understory species declined drastically, others increased, and others were highly variable. Vegetation in old treefall gaps was first to recover and produce fruit, thereby attracting large numbers of birds 3-4 months after the storm's passage. The hurricane itself probably did not kill many forest birds outright, but it set back plant succession, thereby having long-term effects on the forest bird community, which we will continue to monitor.

Habitat Use and Population Biology of the Black-throated Blue Warbler Overwintering in Puerto Rico

Biologist have recently become concerned with the fate of North American migrant birds which overwinter in the tropics. Habitat use and population biology studies of one migrant, the Black-throated Blue Warbler, an indicator species for the Luquillo Experimental Forest have been underway for 2 years. Sexual habitat segregation have been demostrated. Color-banding and territory mapping in three study sites indicate very different population ecologies in different habitats (i.e., territory stability, and overlap, floaters, diet, and age rations). These studies will help in understanding overwinter survival of this species in Caribbean forests.

Environmental Assessment Of The Small Farmer Coffee Project

Some of the new varieties of coffee require less shade. A technical report was written for the U.S. Agency for International Development in Guatemala (Wunderle et al. 1990) to evaluate the potential environmental effects of new coffee cultivation practices on biodiversity. Birds were used to obtain a relative measure of biodiversity. Birds are ideal for this purpose because they are relatively easy to observe and identify and do not require complex sampling techniques to document their presence and thus can be sampled during a project of limited duration. Birds also provide a relative indication of the "health" of the environment in terms of pesticide use. Preliminary analysis (Fig. 1) of avian feeding locations indicates that 57% of the species fed in the shade overstory (N=25), 18% fed in the shade overstory and coffee (N=8), 9% fed in the coffee (N=4), and 16% fed on the ground (N=7). Eight species of North American migrant birds were observed feeding in the shade overstory, while one species also fed in the coffee trees. None of the migrants fed exclusively in the coffee. Four resident species were observed nesting in the

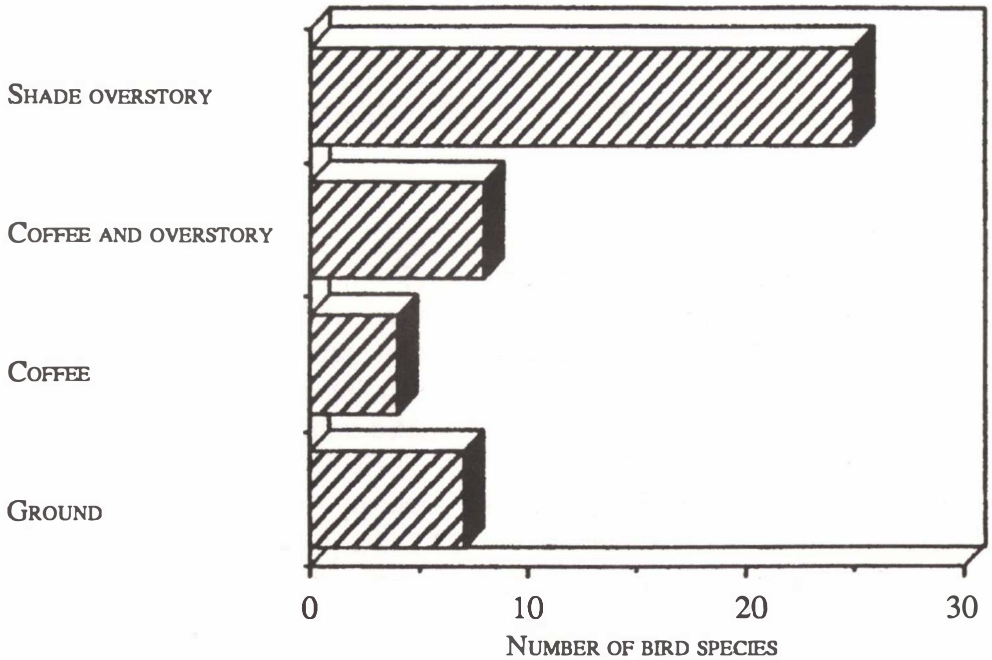

Figure 1. Feeding sites of 44 species of birds observed in montane coffee plantations in Guatemala, illustrating the potential importance of the shade overtory for the maintenance of avian diversity in coffee plantations.

shade trees but no species were found nesting in the coffee.

Shade overstory was responsible for most of the avian diversity found in these coffee plantations. It is likely that similar patterns will be found in other groups of animals, indicating that overstory shade trees play a critical role in maintaining animal diversity in coffee plantations. Further more, many of the shade trees are covered with epiphytes (i.e.,bromeliads and orchids) whichg maintains some of the plant diversity in these plantations. Shade coffee plantations probable serves as refugia for forest dwelling organisms in regions of deforestation. Therefore widespread removal of shade trees in coffee plantations will contribute to the loss of biodiversity.

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OTHER WILDLIFE RESEARCH

Wayne J. Arendt
Wildlife Biologist

In the wake of Hurricane Hugo, much of my research has concentrated on determining the effects of major habitat disturbances on forest birds both at the population and species level.

Short-term effects of Hurricane Hugo on forest birds within three foraging guilds in the Luquillo Experimental Forest (LEF)

To compliment research on bird populations in tabonuco forest, posthugo point-count census routes were established in dwarf forest, colorado forest, and a highly disturbed (pre- and post-hugo) mixed-species woodlot along the northeastern border of the forest. Although habitat destruction was disparate, both within and among different forest types, bird populations within the three main foraging guilds responded similarly in all three forest types.

Avian tramps

Bird species that have evolved superior colonizing abilities and, in short, are generalists in most regards (e.g., habitat and diet) are often referred to as "tramps". In the LEF, three prime examples of avian tramps are the Pearly-eyed Thrasher, Bananaquit, and Red-legged Thrush. The thrasher and thrush are omnivorous, whereas the Bananaquit, although a nectarivore, can revert to eating insects when nectar sources disappear. Each species has an extended breeding season, with multiple clutches each year. Although the thrasher and Bananaquit are found from sea-level to the highest peaks in Puerto Rico, in the LEF the thrasher is most common in colorado forest, whereas the Bananaquit is common in different forest types. The thrush is most common in "edge" and "open" habitat and so is most numerous in the mixed-species woodlot. Two days after the passage of Hugo, each species was found in large numbers in its preferred habitats, taking advantage of fallen fruits, more exposed insects and frog-lizard prey (pers. obs.) (Fig. 1). Unlike the more plant-dependent frugivores and other forest nectarivores, populations of the three tramp species remained stable and increased substantially during the first year following habitat disturbance.

Frugivorous and nectarivorous birds

Populations of most species of frugivorous and nectarivorous birds remained low for the first 5-6 months following habitat destruction (Figs. 2 and 3). Numbers began to increase by March and April. Peaks in May and June are influenced by singing males when most forest birds attempted to nest. Monitoring continues in an attempt to determine if frugivorous bird populations will continue to recover.

Insectivorous birds

Unlike the frugivores and nectarivores, both of which are more dependent upon the reproductive cycles of forest vegetation, populations of most species of forest insectivorous birds remained stable during the first year following habitat disturbance (Fig. 4). Following Hugo, insect populations increased in response to vegetational regeneration. In colorado forest, numbers of the Elfin Woods Warbler appear to have dropped following Hugo, but this could have been due in part to the fact that males were singing in September and October and were silent by December.

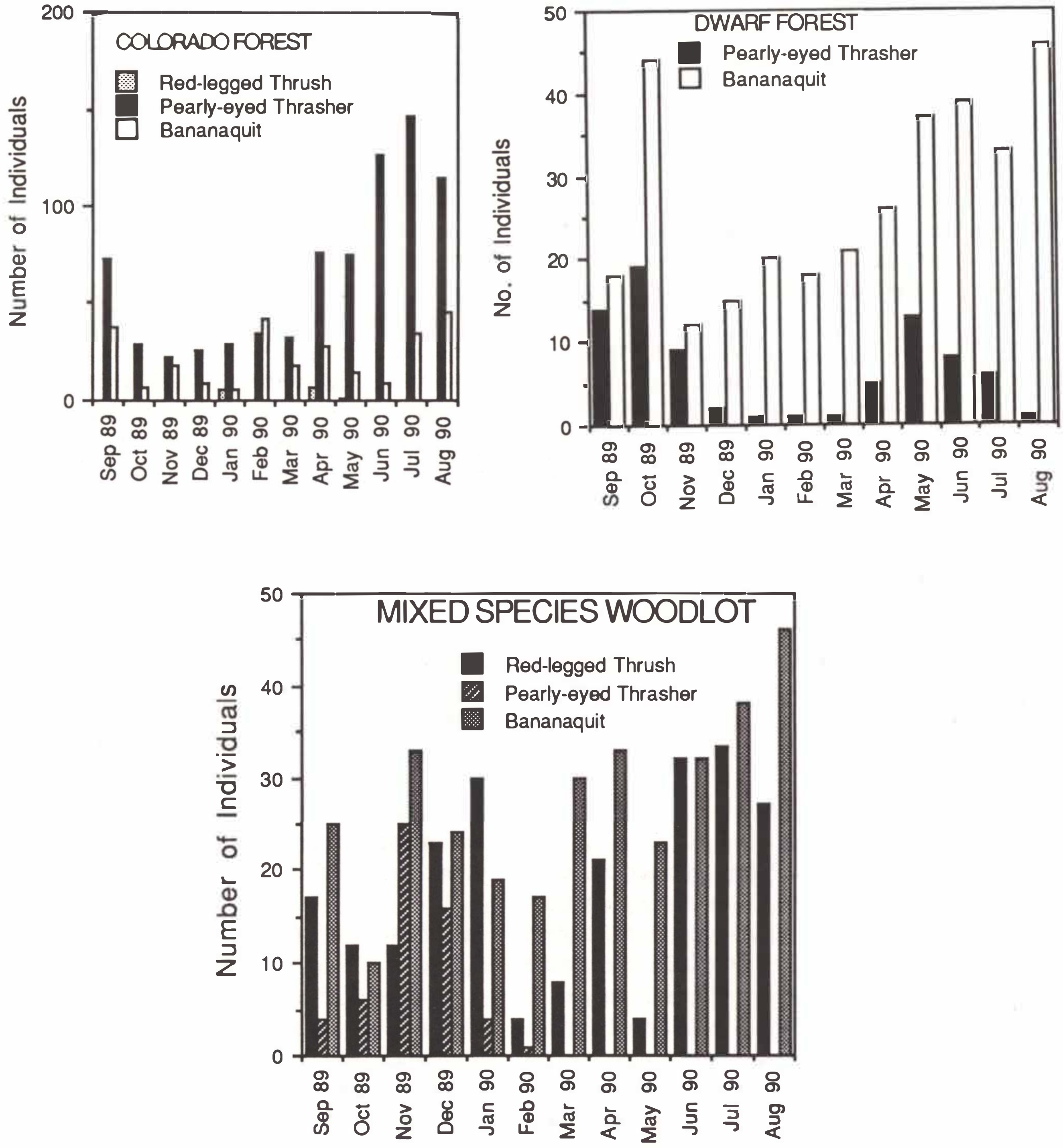

Figure 1. Population fluctuations of three avian tramp species within three major forest types in the Luquillo Experimental Forest during the first year following major habitat disturbances caused by Hurricane Hugo. Note that populations of each species responded well after disturbance in the habitats in which the species is well adapted (Pearly-eyed Thrasher in colorado forest, Red-legged Thrush in open mixed-species woodlot, and Bananaquit in dwarf forest and woodlot).

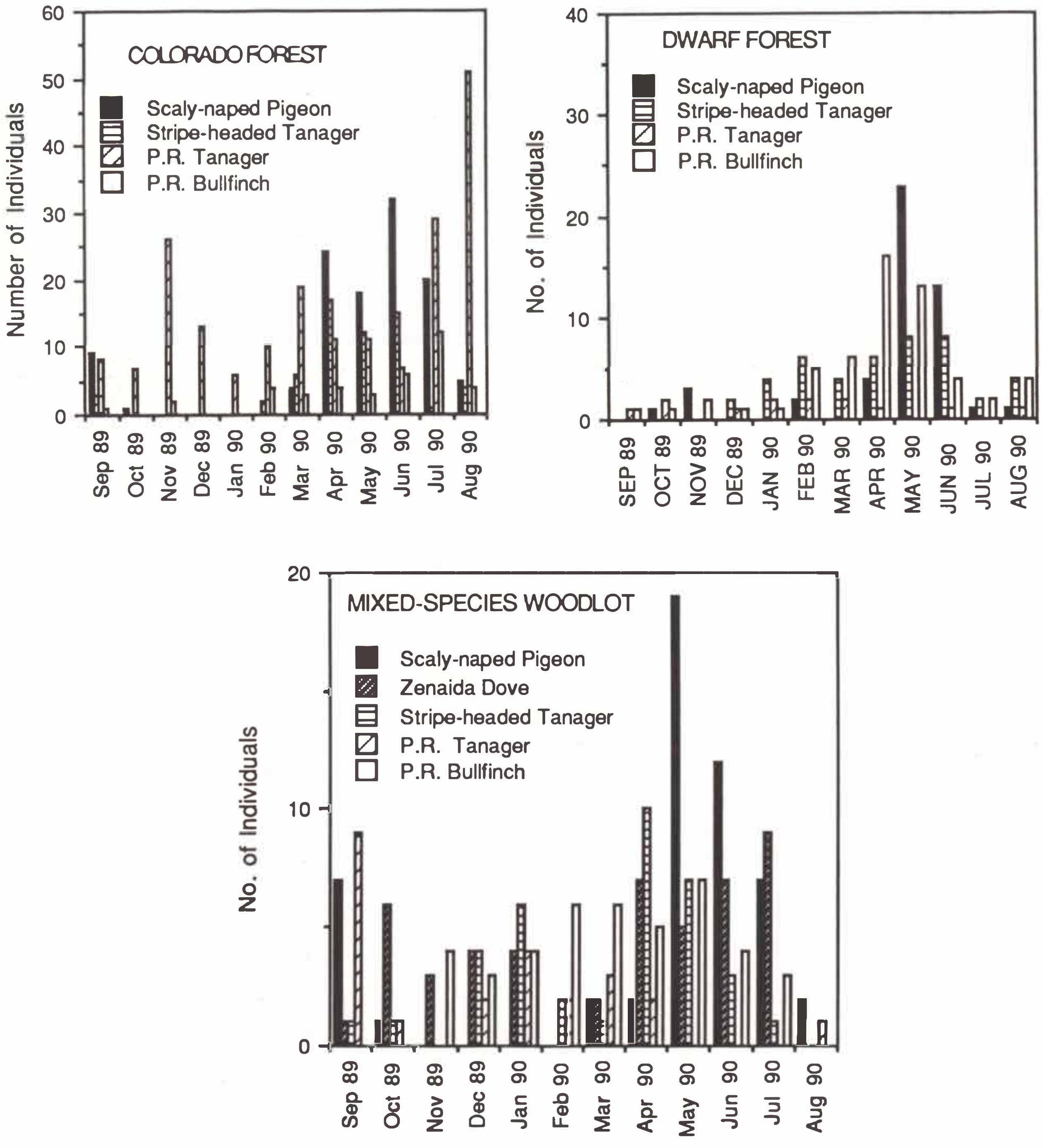

Figure 2. Population fluctuations of frugivorous birds within three major forest types in the Luquillo Experimental Forest during the first year following major habitat disturbances caused by Hurricane Hugo. Note the similar response pattern by most species in all three forest types (generally small numbers for the first 5-6 months, followed by an increase beginning in March and April 1990).

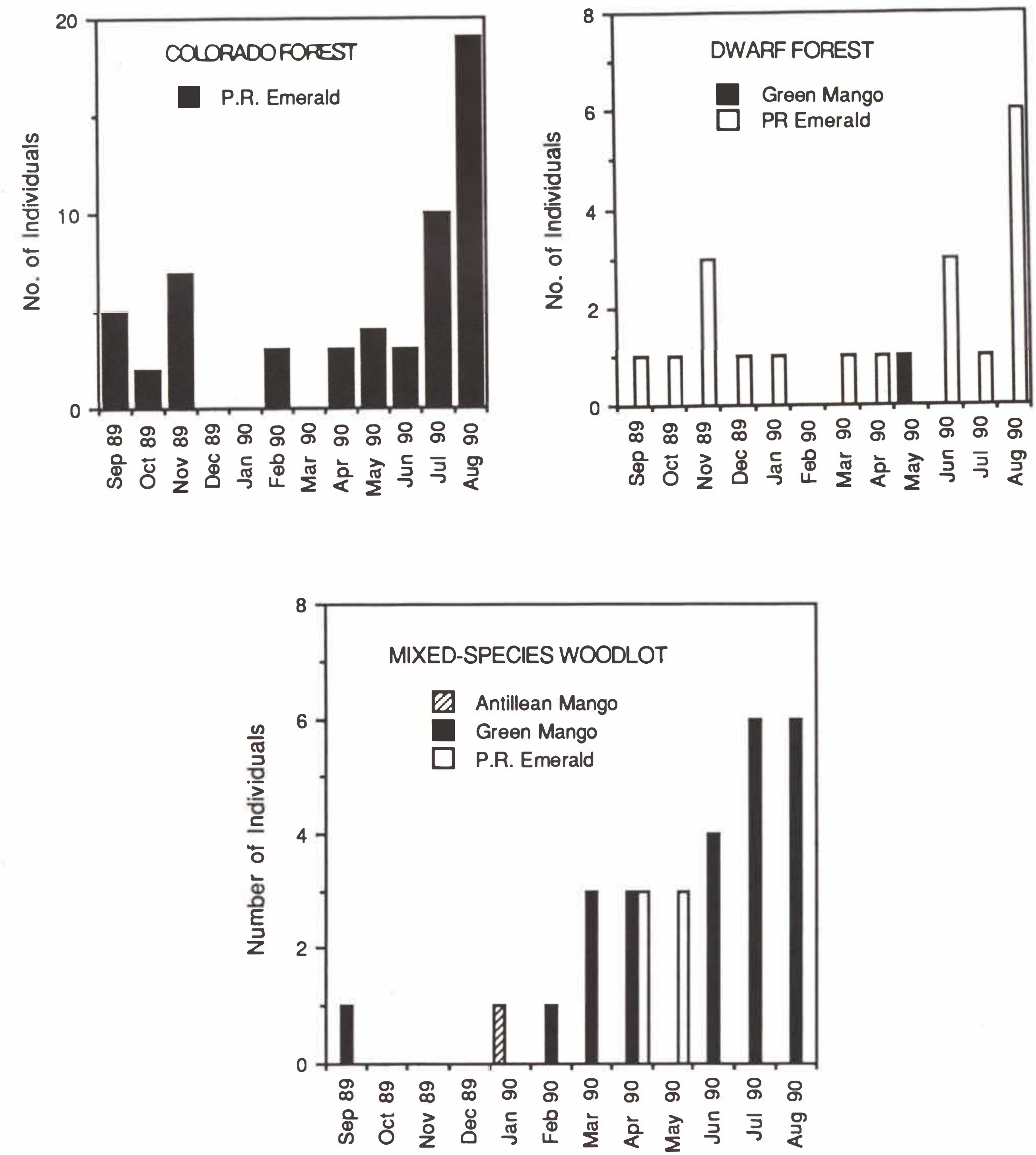

Figure 3. Population fluctuations of nectarivorous birds within three major forest types in the Luquillo Experimental Forest during the first year following major habitat disturbances caused by Hurricane Hugo. Population response patterns were similar to those of the frugivores (Fig. 2).

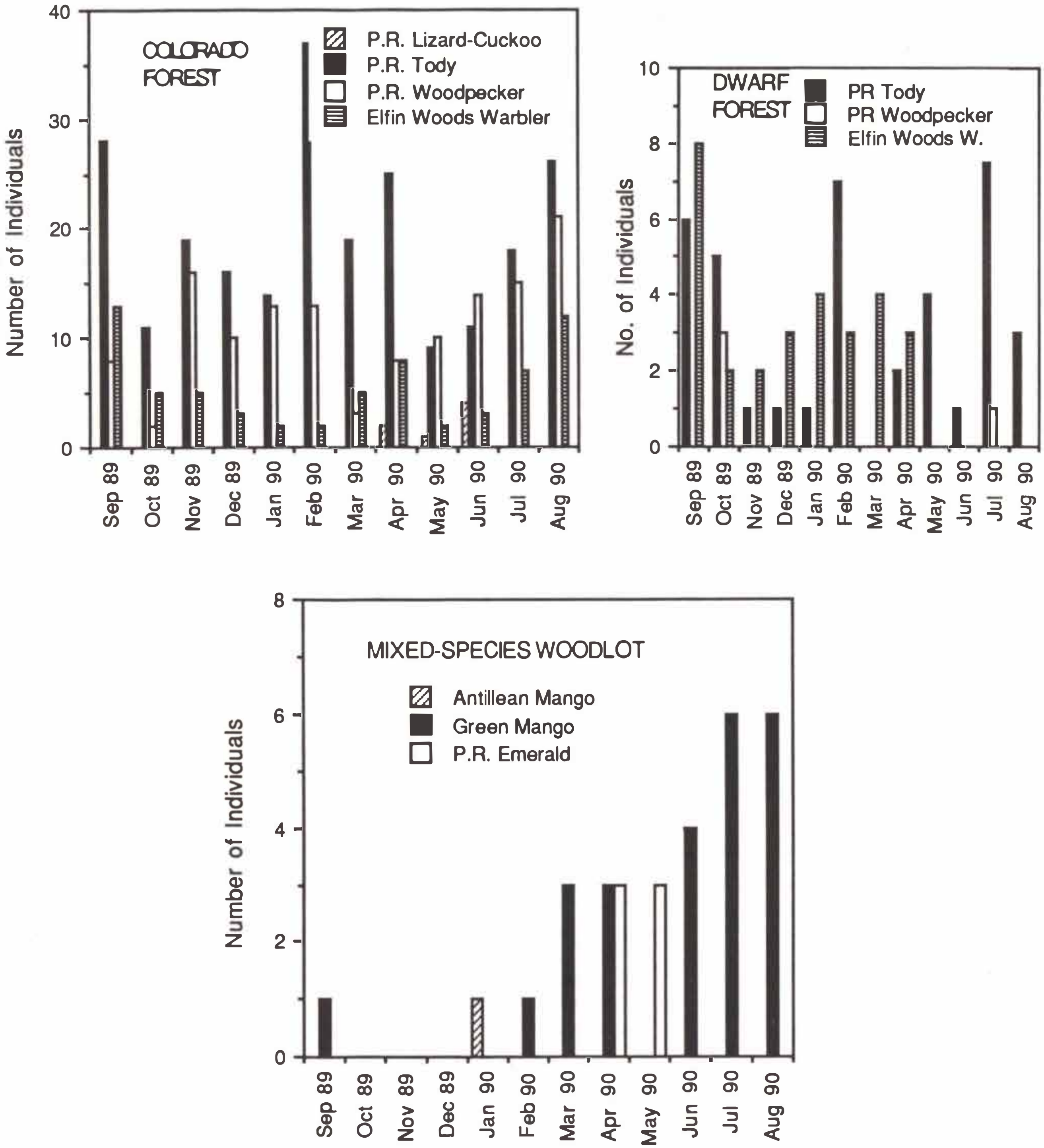

Figure 4. Population fluctuations of resident insectivorous birds within three major forest types in the Luquillo Experimental Forest during the first year following major habitat disturbances caused by Hurricane Hugo. Unlike the frugivores, the insectivores did not show population declines following disturbance. In contrast, within some species such as the tody and woodpecker, populations remained fairly constant in their more preferred habitats each month throughout the first year.

North American Migrant Warblers

Migrant numbers were low in all three forest types following Hugo (Fig. 5). Monitoring of migrant populations will continue throughout the forest to determine the status of each species.

The effect of Hurricane Hugo on Pearly-eyed Thrasher and Redlegged Thrush reproduction

Two species, the Pearly-eyed Thrasher and the Red-legged Thrush were studied to determine the effects of Hurricane Hugo on forest bird reproductive cycles. In the LEF, during ten reproductive seasons (1979-1988) prior to the passage of Hugo, the Pearly-eyed Thrasher nested between November and August (a 9-month breeding season), with most nesting occurring between January and August. Thrasher females typically lay 2-3 normal (not including replacement) clutches per season. As an example, the 1987 breeding season was an average one. It extended from December to August. Thirty-eight females attempted 100 nestings for an average of 2.63 nestings per female. In contrast, during the 1990 breeding season following the major disturbance caused by Hurricane Hugo in the thrasher study areas (primarily colorado forest, with some nest boxes in Tabonuco forest and palm-brakes), 42 females attempted only 53 nestings for an average of 1.26 nestings per female (significantly fewer nestings than in the pre-Hugo years; alpha = 0.05 level, $P < 0.006$, KruskalWallis one-way analysis by ranks). The 1990 breeding season was severly compressed, with nesting occurring within a 2.5-month period (May-early July). Most nesting occurred during June. Unexpectedly, the second major thrasher reproductive season following Hugo (1991) began in September 1990! More than half of the females had laid before the end of December. Some females had fledged young and laid second clutches during the same period.

Similar to the thrasher, the Red-legged Thrush, which also was observed to have an extended nesting period prior to Hugo (February to July during the 1985-1987 seasons), postponed its breeding until late April. However, unlike the prolific thrasher, only one of ten Red-legged Thrush pairs under study successfully nested during the first reproductive bout. Following the May-June season, four pairs attempted breeding, with two pairs successfully rearing young. Possibly due to food shortages, brood reduction was observed in all thrush and some thrasher nests.

The effect of Hurricane Hugo on populations of the Montserrat Oriole, other forest birds, and their habitat

The impact of Hurricane Hugo on Montserrat's forests was severe. Most forest trees throughout the island's three interior mountain ranges suffered damage to their primary branches, but were left standing (52% of the trees sampled in montane forest). However, in dwarf forest on the upper slopes of the South Soufriere Hills, the hardest hit by Hugo, with many trees being uprooted (63% of the 572 trees sampled).

In response to a request made by the World Wildlife Fund, RARE Center, and the Montserrat Government, the effects of Hurricane Hugo on the endemic Montserrat Oriole and other forest birds were investigated. Six months after Hugo more than 100 orioles were observed during a two-week survey, indicating that the species was in no immediate danger (see Arendt 1990 for details). A posthurricane emigration of orioles from the severely damaged dwarf forest on the upper slopes of the South Soufriere Hills occurred. Large concentrations of orioles were found in regenerated forest tracts between 400 and 700 m elevation and within steep-sided

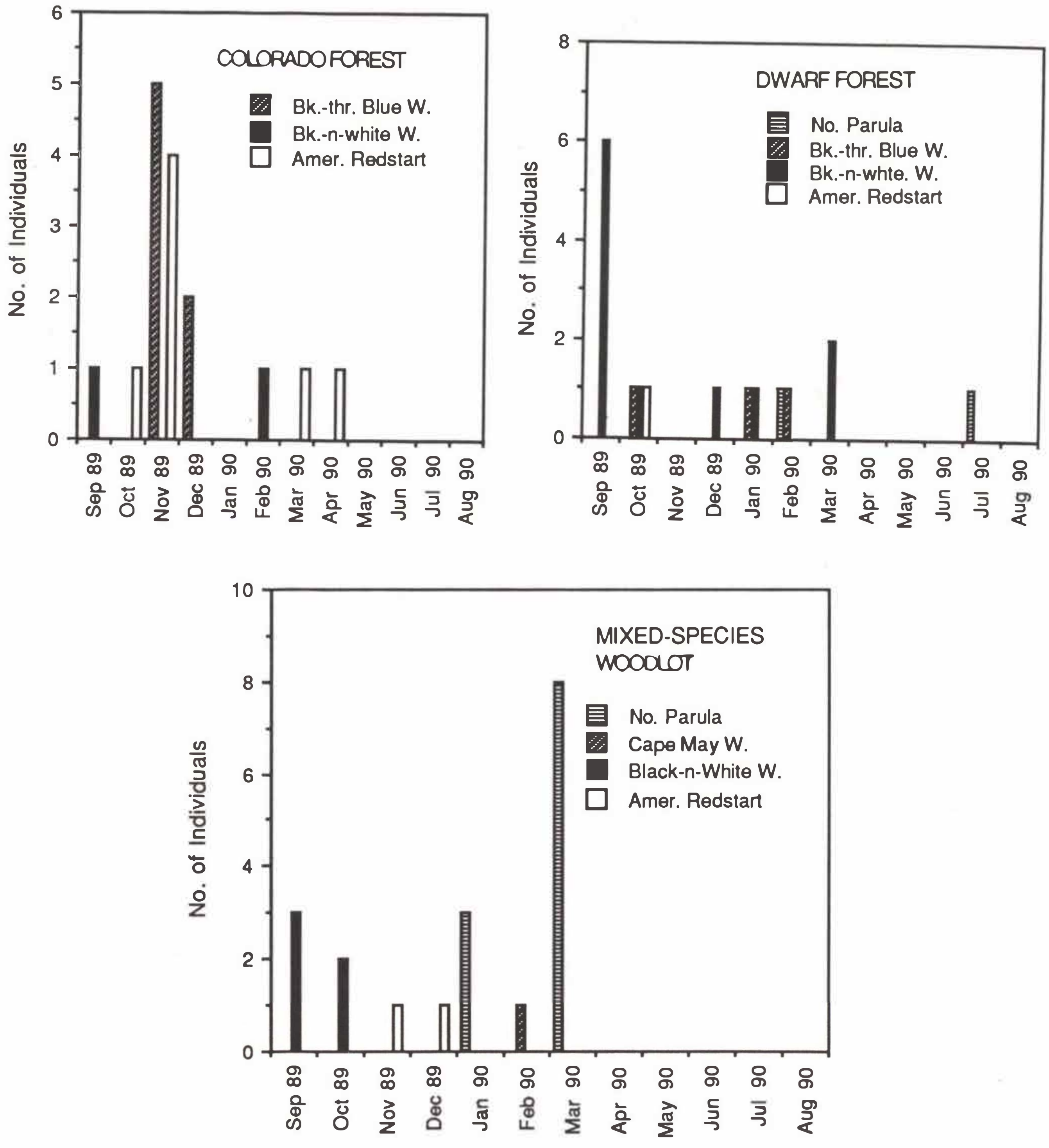

Figure 5. Population fluctuations of North American migrant warblers within three major forest types in the Luquillo Experimental Forest during the first year following major habitat disturbances caused by Hurricane Hugo. Migrant populations were found to be small in all three forest types and most species were not observed during all census in any of the three study areas.

arroyos (ghauts) scattered throughout the foothills of the interior mountains. Orioles were paired by March and post-hurricane reproduction was confirmed when a pair was found feeding two recently fledged young. In addition to the oriole, another 15 species and 619 individuals of Montserrat's forest birds were detected during 90 point-count censuses in forested areas within the three major interior mountain ranges. With one exception, the Green-throated Carib (a nectarivore), no species appears to be in trouble as a result of Hurricane Hugo, although it may be too early to detect critical population declines that could occur from potential shortages of food, foraging and nesting habitat, etc. As in Puerto Rico, two avian tramp species, the Pearly-eyed Thrasher and the Bananaquit were the most abundant and most widespread species following habitat disturbance.

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IMPACT OF HURRICANE HUGO ON THE PUERTO RICAN PARROT AND INTER-AGENCY RESTORATION EFFORTS

Wayne J. Arendt
Wildlife Biologist

Parrot Numbers

Wild Flock

The relict Puerto Rican Parrot population inhabiting the Luquillo Mountains in northeastern Puerto Rico had grown from a low of 13 birds in 1975 to an estimated 47 individuals following the 1989 breeding season. However, pre-breeding season count totals (a more realistic estimate of the effective population) averaged 30 parrots over a five-year period from 1984 to 1989, suggesting that the population has about doubled since its 1975 hiatus. Unfortunately, the widespread physical damage and habitat disturbance in parrot areas caused by Hurricane Hugo on September 18, 1989 resulted in a loss of one third to about one half of the population. Following the hurricane, and due in part to a poor reproductive effort during the 1990 breeding season, the wild flock parrot numbers have been reduced to about 25 individuals (Fig. 1).

Captive Flock

Prior to Hurricane Hugo, there were 52 Puerto Rican Parrots in captivity at the Luquillo Aviary. There are now 57 individuals as a result of the production of five chicks from two breeding pairs during the 1990 season.

Post-Hugo Reproductive Efforts

Parrot reproduction normally extends from January to July. Following Hugo, the 1990 breeding season was delayed 2-3 months, a trend observed in other forest birds. Most breeding activities occurred from April to June, a period when no population counts were conducted (Fig. 1). Only three reproductive efforts by Puerto Rican Parrots were confirmed during the 1990 breeding season, although a fourth pair was observed showing signs of nesting behavior early in the season. Single nesting attempts were made by at least two traditional nest pairs at South Fork 1 and 2, and a possibly newly formed pair at East Fork 3. Although five chicks hatched from eight fertile eggs, nest success occurred only at East Fork 3, where two chicks fledged in August, much later than in previous years. The South Fork 2 nest failed after the adult female

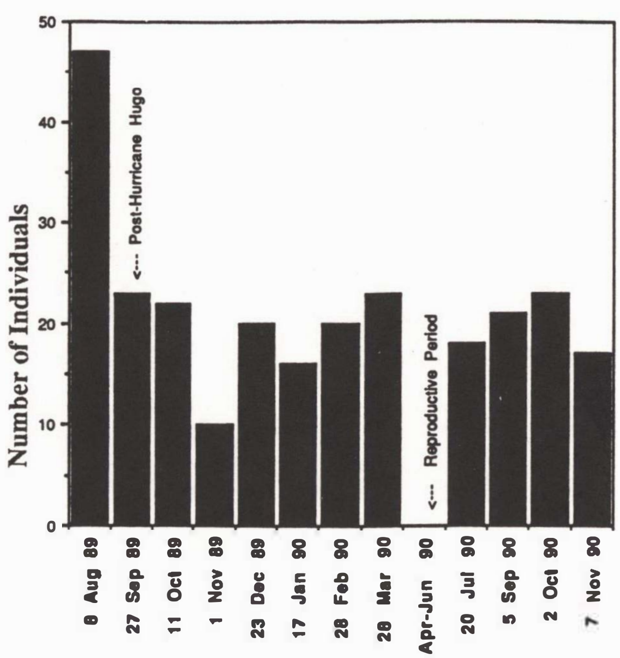

Figure 1. Pre- and post-Hurricane Hugo population counts of the endangered Puerto Rican Parrot. Note that the population remains at about half its pre-hurricane total following the 1989 breeding season. Count data were taken from a manuscript in preparation by Francisco J. Vilella.

disappeared and, presumably, fell prey to a Red-tailed Hawk. A hawk was observed stooping on the female before her disappearance and, subsequently, one was observed attempting various strikes on the adult male.

Restoration Efforts

Inter-agency coordination continues in implementing mitigation measures to bolster the hurricane-depleated parrot population. Personnel from three federal and state agencies continue to carry out post-hurricane nest observations and population censuses to monitor parrot reproductive success, survival, and distribution. The Fish and Wildlife Service used experienced nest watchers to enhance the probability of reproductive success at each nest during the 1990 breeding season. To maximize parrot-count accuracy, FWS personnel have resumed the use of afternoon counts, followed by early morning counts by the same observers in the same areas. The Service has also implemented a new, more camouflaged and thus less intrusive, parrot blind design. To increase inter-agency communication, and to broaden the general public's awareness and appreciation for the parrot, the FWS is initiating a parrot newsletter. Following Hugo, Caribbean National Forest wildlife biologists reconstructed or repaired 4 natural parrot nests, 12 artificial parrot nests, 25 lookout towers, 8 blinds, and 24 Pearly-eyed Thrasher nest boxes. In addition, 13 km of trail to nesting areas have been repaired and enhanced.

Parrot's Future

Currently, there are a number of research and management activities that shed a light of hope for the future of the Puerto Rican Parrot. These include: 1) research on the parrot's genetic make-up to determine phylogenetic lineages (relatedness) and the harmful effects of inbreeding in an effort to enhance its reproductive potential and survival, 2) vocalization studies to determine if individual parrots can be recognized by their calls, 3) marking studies to determine best methods for individual identification of free-flying psittacines, 4) studies on territorial pairs of Puerto Rican Parrots, 5) studies on the dynamics of cavity formation in traditional parrot nest-trees, 6) fruit phenology studies of keystone forest tree species, many of which are food-trees used by parrots. Two major objectives of the phenology studies are to determine patterns of fruit production, and thus the availability of parrot foods on a spatiotemporal basis, and the trees' reactions (e.g., regeneration strategies and recrudescence periods) to habitat disturbances, both natural and human-induced.

In the captive flock, new cage designs by T. Sorenson show real potential for enhancing strong pair bonds and reproductive success in captive parrots, while the newly established parrot aviary at Rio Abajo will facilitate reintroduction of captive-bred parrots into traditional areas. The importance of many, geographically separated parrot flocks became more evident after viewing the severe and widespread habitat destruction caused by Hurricane Hugo and its toll on the parrots of Luquillo.

WILDLIFE RESEARCH

Juan A. Torres
Wildlife Biologist

During the past year I conducted research on the impact of Hurricane Hugo on insects, reviewed the literature on forest entomology in the Luquillo Mountains, and publish a paper on the fire *ant Solenopsis invicta* (Torres 1990).

Influence of Hurricane Hugo on insects

Hurricane Hugo struck the north east portion of Puerto Rico on September 18, 1989. Maximum winds were approximately 225 km/hr. Winds blew for about 18 hour in the Luquillo Mountains causing extensive damage to vegetation. After the hurricane, pulse of pioneer plants invaded in the forest.

By October there were increases in the abundance of Diptera, especially fruit flies. This was probably a consequence of the increase in rotten fruit; although the possibility of vertical displacement of fruit flies cannot be rule out. Damaged trees and dead wood were quickly attacked by bark beetles (Scolytidae) and pin-hole borers (Platypodidae). High intensity of activity of these groups was recorded during the months of November and December.

The greatest insect outbreaks occurred during the spring and early summer after the hurricane (April-June 1990). Fifteen Lepidoptera species were recorded in outbreaks. All the Lepidoptera fed on pioneer vegetation that entered the forest after the hurricane. The most spectacular outbreak was the one by *Spodoptera eridania* (Noctuidae). This moth fed on 56 plant species belonging to 32 families. The end of the *S. eridania* outbreak was related to the exhaustion of its preferred hosts and parasitism by ichneumonids (Hymenoptera). Parasitism by tachinids (Diptera) might have contributed to the reduction in the abundance of the other Lepidoptera.

Forest entomology

Acomprehensive review of forest insects is presently being published as a U.S. Forest Service General Technical Report. Emphasis is on to research conducted in the Luquillo Experimental Forest (Luquillo Mountains). The review provides an introduction for those interested in pursuing research in the insects inhabiting the Luquillo Experimental Forest and as a guide to identify possible insect pests. The review consist of four sections. The first deals with basic ecology. The second treats forest insect pests. The third section deals with those insects that attack dead wood or woods during drying processes. The fourth section consists of an annotated bibliography that includes the systematics and taxonomy of different insect orders in Puerto Rico.

Fire ants

The fire ant *Solenopsis invicta* invaded Puerto Rico a few year ago. Its presence has caused alarm among the public and farmers. The ecology of this ant in the United States, Brazil, and Puerto Rico was published (Torres 1990). Most research information on this ant is inadequate to answer questions about its effects on wildlife, public health, and crops. This is due to lack of appropriate experimental controls or experiments without replication.

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WATERSHED MANAGEMENT

F.N. Scatena
Hydrologist

During 1990, watershed research concentrated on monitoring the impacts and natural reconstruction of the Bisley forest after Hurricane Hugo passed over the area in September 1989. In addition to the existing long-term studies, new research efforts were initiated on herbaceous vegetation, phenology, microclimate, and seedlings. The first Doctoral thesis based on the Bisley area was also completed (Basnet 1990).

Resistance of the dominant tree in the forest, Tabonuco (*Dacryodes excelsa*) to hurricanes was well demonstrated in Hurricane Hugo. Although nearly every tree in the forest was damaged to some extent, tabonuco was the only species which showed significant resistance to damage by the hurricane. Damage also varied significantly among size class, with stems >60 cm in diameter receiving the greatest damage (Basnet 1990, Koning 1990).

The intensity of damage was significantly greater in valleys than on ridges and slopes. Prior to the hurricane, toposequences had been observed for vegetation (Heaton and Letourneau 1989, Basnet 1990), throughfall and canopy structure (Scatena 1990a), soil and other ecological factors. Ridges were typically dominated by stands of tabonuco's while riparian areas had a distinct and generally successional type vegetation (Heaton and Letourneau 1989; Scatena 1990b). The dynamics of the riparian area also appeared to be important to aquatic nutrient cycles (Bowden et al. 1990), supply of woody debris to stream channels (Covich and Crowl 1990), and the management of culverts and other channel structures (Scatena 1990c).

One year after the hurricane, 45% of the watersheds was covered by herbaceous vegetation (Chinea 1990a). A total of 41 herbaceous species were identified and composition was more species-rich than previously reported in closed forest. Principal components analysis indicates that heterogeneity in light regimes accounts for some of the herbaceous community differentiation. Population sizes of seedlings of the exotic invasive tree, *Albizia procera* also correlated significantly with light conditions (Chinea 1990b).

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Table 1. Activities Institute staff participated in during FY 1988-89.

Commonwealth of Puerto Rico	National	International
-Reviewed articles and/or research proposals for Caribbean Journal of Science, and the Department of Natural Resources of Puerto Rico	-Various meetings of the United States Man and the Biosphere Program	-Addressed the Caribbean Foresters Association
-Weekly technical counsel to USDA Forest Service and Puerto Rico Department of Natural Resources	-Reviewed research proposals for the National Science Foundation, National Geographic Society, and the Smithsonian Institution	-Met with forestry investment manager in preparation for work on Dominica
-About a dozen lectures to courses in tropical forestry and ecology at the University of Puerto Rico	-Reviewed articles for the journals: Animal Behavior, Auk, Journal of Field Ornithology, and the Condor	-Speaker at Symposium on Tropical Erosion, Fiji
-Invited lectures to: Department of Biology, University of Puerto Rico; University of Puerto Rico at Mayaguez Campus; Environmental Program of the University of Puerto Rico; Biology Department, InterAmerican University	-Reviewed Yale's School of Forestry program.	-Consultancy for USAID in Guatemala
-Sponsored and supervised undergraduate research at University of Puerto Rico,Cayey	-Served on panel in workshop of Smithsonian Institution on sustained yield in tropical forestry	-Presented paper to the Society for the Study of Caribbean Ornithology at Jamaica
-Presented paper at symposium of the Department of Natural Resources of Puerto Rico	-Presented paper on tropical silviculture at David Smith retirement ceremony at Yale University	-Attended IUFRO XIX World Congress held in Canada
-Counsel to graduate forestry student at University of Colorado	-Presented paper at Joint Meeting of Wilson Ornithological Society & Association of Field Ornithologists, Norton, Massachussetts	-Served on ITTO team studying sustained yield forestry in Sarawak
	-Invited lectures to: Marine Policy Institute, Woods Hole Oceanographic Institute, Massachussetts; Nutall Ornithological Club, Harvard University; Ecological Society of	-Codirected workshop of Silvicultural Study Group of North American Forestry Commission at Escarcega, Mexico
		-Presented panel statement XIX IUFRO World Congress in Montreal, Canada

Table 1. (cont'd).

Commonwealth of Puerto Rico	National	International
-Technical counsel to Puerto Rico Chamber of Commerce on potential for timber industry in Puerto Rico	America; Department of Botany at the University of Florida; Oak Ridge National Laboratory; Ecology Program at the University of Tennessee; students and staff at the Syracuse School of Forestry	-Technical counsel to Caribbean Natural Areas Research Institute on Cottage Forestry Program in Dominica
-Training of Boy Scout camp counsellors in natural history	-Presented paper on tropical forestry at Hasking College, Ohio	-Participated on rare plant preservation consultation of Caribbean Natural Areas Research Institute in St. Lucia
-Judged local Science Fair, and Science Congress of High School students	-Addressed the Soil Conservation Associations National Meeting, the California Science Teachers Association, and the American Forestry Association in Washington, D.C.	-Moderated a session of the General Annual Meeting of the Caribbean Conservation in St. Lucia
-Several radio and television programs	-Keynote address to the Annual Convention of the Society of American Foresters	-Paper to Forest-90 International Symposium in Manaus, Brazil
-Several newspaper interviews	-Paper to the Association of Tropical Biologists at Richmond, Va.	-Selected line planting sites for research in Grenada
-Reviewed research program at the Center for Energy and Environment Research, University of Puerto Rico	-Paper to the National Meeting on Climate Change, Washington, D.C.; Soil carbon workshop at Corvallis, Oregon; and Tree Mortality Workshop at Corvallis, Oregon	-Lectured on secondary forest inventory and line planting to Peruvian forestry technicians
-Organized and led many field trips to the Luquillo Experimental Forest	-Speaker at the American Water Resources Association	-Addressed the Ministers of Agriculture and the Environment of Caribbean islands at Saint Lucia
-Conducted undergraduate course on forest rehabilitation at the University of Puerto Rico		-Reviewed Brazilian forestry research program
-Advised the U.S. Navy on establishment of a new mahogany plantation on Vieques		-Developed a Project Paper for the Peten region for USAID

Table 1. (cont'd).

Commonwealth of Puerto Rico	National	International
-Established a 2.5 acre dry land reforestation demonstration within the "Albergue Olimpico" in Salinas, P.R. -Participated throughout the year with Caribbean National Forest in drafting amended Land and Resource Management Plan and plan for El Portal Visitors Center	-Participation in all Scientists Meeting and Project Leader's Meeting of the Southern Forest Experiment Station -Hosted numerous visitors including: *authors for national magazines *Beta Beta Beta National Convention at the Luquillo Experimental Forest *Scientists from the Woods Hole Marine Laboratory *Professors from the Yale School of Forestry *Representatives of the National Science Foundation, Long Term Ecological Research -Paper at the All Scientists Meeting of the Long Term Ecological Research Program of NSF, Estes Park, Colorado; Global Change Workshop at Woods Hole Mass, and Long Term Ecological Research Program annual meeting in San Juan, P.R. -Conducted Chautauqua course on tropical ecology for American college professors -Consulted for St. Thomas Public works on health of old roadside mahogany trees	-Global Change Workshop at FAO headquarters, Rome -Hosted a group of visitors from the British Virgin Islands Department of Agriculture -Visited the British Virgin Islands at the invitation of the B.V.I. Department of Agriculture and advised on establishing species adaptability tests and extension forestry -Assisted personnel from CATIE in making provenance collections of *Swietenia mahagoni*, *S. macrophylla* and *S. macrophylla* x *mahagoni* -Hosted a group of foresters USAID-sponsored training from Peru on visit to Cambalache and Rio Abajo -Traveled to Antigua, West Indies at the invitation of the Antigua Department of Agriculture to advise on setting up species adaptibility trials and a forestry nursery -Sent out more than 50 seed orders to researchers and land managers around the world for species trials

Table 2. Committees or delegations with Institute staff participation

Commonwealth of Puerto Rico	National	International
-Graduate student committees at the University of Puerto Rico	-U.S. Man and the Biosphere Program, Executive Committee	-Research Committee of FAO's Latin America Forestry Commission
-Puerto Rico Sea Grant Advisory Committee	-U.S. Man and the Biosphere Program, Tropical Ecosystems Directorate	-Caribbean Foresters Society
-Vieques Resource Management Advisory Committee	-Puerto Rican parrot Inter-Agency Working Group Committee	-Counselor of the Association of Tropical Biologists
-Puerto Rico Science Teachers Association Advisory Board	-Global Change Committee	-Board of Governors of the Society for Conservation Biology
-Editor Acta Cientifica, the Journal of the Science Teachers Association	-Long Term Ecological Research Coordinating Committee	-Editorial board of Vegetatio
-Consejo Consultivo del Programa del Patrimonio Natural	-Board of Overseers of Harvard College, Committee to visit Department of Organismic and Evolutionary Biology	
-Scientific Editorial Board for the Caribbean Journal of Science	-Review Team for the Department of Forestry, School of Forest Resources and Conservation, University of Florida	
	-National Research Council Committee on Sustainable Agriculture and the Environment in the Humid Tropics	
	-Blue Ribbon Committee to review the research program for the Fish and Wildlife Service Patuxent Wildlife Research Laboratory	

Table 3. Visitors to the Institute of Tropical Forestry.

Acevedo, Pedro
Smithsonian Institution
Washington, D.C.

Adams, Michael
Jacksonville, Florida

Alam, Abul
CFTC Agricultural Engineer
Department of Agriculture
Road Town, Tortola, B.V.I.

Arias, Antonio
Caparra, Puerto Rico

Basnet, Khadga
Rutgers University
Piscataway, New Jersey

Bauer, Jerry
USAID/Guatemala

Brown, Sandra
Department of Forestry
University of Illinois
Urbana, Illinois

Burns, Russell
Timber Management Research
USDA Forest Service
Washington, D.C.

Chalmers, Dan
Consultant
Food and Agriculture Organization
of the United Nations
Tropical Forestry Action Plan
Barbados, West Indies

Cuevas, Elvira
Instituto Venezolano de Investigación
y Capacitación Caracas
Venezuela

Dale, Virginia
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Deravariere, Rosmond
Department of Agriculture
Tortola, B.V.I.

Deuerling, Timothy
Jacksonville, Florida

Fetcher, Ned
Department of Biology
University of Puerto Rico
Rio Piedras, Puerto Rico

Flint, Elizabeth
Department of History
Duke University
Durham, North Carolina

Gross, Louis J.
Math Deptartment
University of Tennessee
Knoxville, Tennessee

Hager, Johannes
Departamento de Vida Silvestre
Santo Domingo, República Dominicana

Hall, Charles A.S.
School of Environmental Science
and Forestry
State University of New York
Syracuse, New York

Harcharik, David
International Forestry
USDA Forest Service
Washington, D.C.

Hill, Larry
USDA Forest Service (Retired)
Maryland

Table 3. (cont'd).

Houghton, R.A.
Woods Hole Research Center
Woods Hole, Massachusetts

Iverson, Louis
Illinois Natural History Society
Champaign, Illinois

Jiménez, Diego
Forest Service Director
Department of Natural Resources
San Juan, Puerto Rico

Jiménez, Jorge A.
Coordinator, Laboratorio de Manglares
y Ecología Estuarina
Universidad Nacional
Escuela de Ciencias Biologicas
Heredia, Costa Rica

Kumar, Jammi S.
Chief Agriculture Officer
Department of Agriculture
Road Town, Tortola, B.V.I.

Lea, Russell
Department of Forestry
North Carolina State University
Raleigh, North Carolina

Little, Jr., Elbert L.
Retired Botanist
USDA Forest Service
Washington, D.C.

Medina, Ernesto
Instituto Venezolana de Investigación
y Capacitación
Caracas, Venezuela

Mengel, Dennis
Department of Forestry
North Carolina State University
Raleigh, North Carolina

Meyers, J. Michael
US Fish and Wildlife Service
Palmer, Puerto Rico

Murray, Judi
USDA Forest Service
Tongass National Forest
Juneau, Alaska

Neary, Daniel
Intensive Management Practices
Assessment Center
USDA Forest Service
Gainesville, Florida

Parks, Peter J.
Forestry and Environmental Studies
Duke University
Durham, North Carolina

Payne, Brian
International Forestry
USDA Forest Service
Washington, D.C.

Plaeger, Russell
USDA Forest Service
Portland, Oregon

Quiñones, Francisco
Caparra, Puerto Rico

Richards, John F.
Department of History
Duke University
Durham, North Carolina

Rodríguez L., Alberto
Peace Corps
Santo Domingo, Dominican Republic

Santiago-Vélez, Vivian
University of Puerto Rico
Ponce, Puerto Rico

Table 3. (cont'd).

Siccama, Tom
School of Forestry and Environmental Studies
Yale University
New Haven, Conneticut

Skole, David
Institute for Study of Earth, Oceans, and Space
University of New Hampshire
Durham, New Hampshire

Smith, Dino
Biology Department
Texas Tech University
Lubbock, Texas

Smith, Ethlyn E.
Permanent Secretary
Government of British Virgin Islands

Snyder, Noel
US Fish and Wildlife Service
California

Velázquez, Martha M.
Carolina, Puerto Rico

Velilla, Marinelly
Bayamon, Puerto Rico

Vose, Jim
Coweeta Hydrologic Laboratory
Southeastern Forest Experiment Station
USDA Forest Service
Otto, North Carolina

Walker, Kathy
Forest Products Laboratory
USDA Forest Service
Madison, Wisconsin

Willig, Michael R.
Biology Department
Texas Tech University
Lubbock, Texas

Appendix
Apéndice

A. Recent Publications of the Institute of Tropical Forestry
(* indicates reprints available for distribution).

Publicaciones recientes del Instituto.
(* indica disponibilidad de separatas para distribución).

001 Arendt, W.J. 1990. Impact of Hurricane Hugo on the Montserrat Oriole, other forest birds, and their habitat. Report to World Wildlife Fund-US, RARE Center, Montserrat Government, Montserrat National Trust, and United States Department of Agriculture, Forest Service. 28 p.

002 Brown, S. and A.E. Lugo. 1990. Tropical secondary forests. Journal of Tropical Ecology 6:1-32.

003 Brown, S. and A.E. Lugo. 1990. Effects of forest clearing and succession on the carbon and nitrogen content of soils in Puerto Rico and U.S. Virgin Islands. Plant and Soil 124:53-64.

004 Brown, S., A.J.R. Gillespie, and A.E. Lugo. 1989. Biomass estimation methods for tropical forests with applications to forest inventory data. Forest Science 35(4):881-902.

005 Brown, S., A.J.R. Gillespie, and A.E. Lugo. 1990. Use of forest inventory data for biomass estimations of tropical forests. Pages 1046-1055 *in* Global Natural Resource Monitoring and Assessments: Preparing for the 21st Century, Proceedings of the International Conference and Workshop, Vol. 3. September 24-30, 1989, Fondazione G. Cini, Isle San Giorgio Maggiore, Venice, Italy. American Society for Photogrammetry and Remote Sensing Bethesda, Maryland, USA.

006 *Chinea-Rivera, J.D. 1990. *Ceiba pentandra* (L.) Gaertn. Ceiba, Kapok, Silk cotton tree. Bombacaceae, Bombax family. SO-ITF-SM-29. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 4 p.

007 Faaborg, J. and W.J. Arendt. 1990. Long-term declines in winter resident warblers in a Puerto Rican dry forest. American Birds, Christmas Bird Count 43(4):1226-1230.

008 *Francis, J.K. 1990. *Syzygium jambos* (L.) Alst. Rose apple. Myrtaceae, Myr family. SO-ITF-SM-26. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 4 p.

009 *Francis, J.K. 1990. *Hymenaea courbaril* (L.) Algarrobo, locust. Leguminosae, Legume family. Caesalpinioideae, Cassia subfamily. SO-ITF-SM-27. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 5 p.

010 *Francis, J.K. 1990. *Fraxinus undei* (Wenzig) Lingelsh. Fresno, tropical ash. Oleaceae, Olive family. SO-ITF-SM-28. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 4 p.

011 *Francis, J.K. 1989. Merchantable volume and weights of mahoe in Puerto Rican plantations. Research Note SO-355. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 4 p.

012 *Francis, J.K. 1989. The Luquillo Experimental Forest Arboretum. Research Note SO-358. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 8 p.

013 *Francis, J.K. 1990. *Citharexylum fruticosum* L. Pendula, Fiddleweed. Verbenaceae, Verbena family. SO-ITF-SM-34. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 4 p.

014 *Francis, J.K. [n.d.]. *Khaya nyasica* Stapf. ex Baker. Family: Meliaceae. Burns, R.M., tech. coord. and Mosquera, M., ed. (Spanish version). Useful Trees of Tropical North America. Silvicultural Study Group. North American Forestry Commission, publication number 3. Washington, D.C., USA.

015 *Francis, J.K. 1989. *Mammea american* L. Mamey, Mammee-apple. Guttiferae, Mangosteen family. SO-ITF-SM-22. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 4 p.

016 *Francis, J.K. 1989. *Terminalia catappa* L. Indian almond, Almendra. Combretaceae, Combretum family. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 4 p.

017 *Francis, J.K. 1989. *Tabebuia donnell-smithii* Rose. Primavera. Bignoniaceae, Bignonia family. SO-ITF-SM-25. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 4 p.

018 *Francis, J.K. 1990. *Spathodea campanulata* Beauv. African tulip tree. Bignoniaceae, Bignonia family. SO-ITF-SM-32. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 5 p.

019 Gillespie, A.J.R., S. Brown, and A.E. Lugo. 1990. Biomass estimates for tropical forests based on existing inventory data. Pages 246-253 *in* La Bau, Vernon J., tech. coord., Proceedings, State-of-the-Art Methodology of Forest Inventory: A Symposium. General Technical Report PNW-GTR-263. United States Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon, USA.

020 Kangas, P.C. and A.E. Lugo. 1990. The distribution of mangroves and saltmarsh in Florida. Tropical Ecology 31(1):32-39.

021 Lugo, A.E. and S. Brown. 1988. The wetlands of Caribbean islands. Acta Científica 2(2-3):48-61.

022 Lugo, A.E. 1990. Influence of green plants on the world carbon budget. Pages 79-86 *in* Veziroglu, T. Nejat, editor, Environmental Problems and Solutions: Greenhouse Effect, Acid Rain, Pollution. Hemisphere Publishing Corporation, New York, New York, USA. [Also printed in 1983 in T.N. Veziroglu, (editor). Alternative energy sources V. Part E: Nuclear/Conservation/ Environment. Elsevier Science Publishers B.V. Amsterdam, The Netherlands].

023 Lugo, A.E., editor. 1990. Annual Letter 1988-89. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, Río Piedras, Puerto Rico.

024 Lugo, A.E., editor. 1988. Acta Científica 2(2-3).

025 Lugo, A.E., D. Wang, and F.H. Bormann. 1990. A comparative analysis of biomass production in five tropical tree species. Forest Ecology and Management 31:153-166.

026 Lugo, A.E. 1990. Tropical forest conservation: getting the act together. Conservation Biology 4(1):109-110 (book review).

027 *Parrotta, J.A. 1990. *Paraserianthes falcataria* (L.) Nielsen. Batai, Moluccan sau. Leguminosae (Mimosoideae), Legume family. SO-ITF-SM-31. United States Department of Agriculture, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 5 p.

028 *Parrotta, J.A. 1990. *Tamarindus indica* L. Tamarind. Leguminosae (Caesalpinioideae), Legume family. SO-ITF-SM-30. United States Department of Agriculture, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 5 p.

029 *Parrotta, J.A. 1989. *Dalbergia sissoo* Roxb. Sissoo, Indian rosewood. Leguminosae (Papilionoideae), Legume family. SO-ITF-SM-24. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 5 p.

030 *Parrotta, J.A. and J.K. Francis. 1990. *Senna siamea* Irwin & Barnaby. Yellow cassia, minjri. Leguminosae (Caesalpinioideae), Legume family. SO-ITF-SM-33. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 7 p.

031 Scatena, F.N. 1990. Watershed scale rainfall interception on two forested watersheds in the Luquillo Mountains of Puerto Rico. Journal of Hydrology 113:89-102.

032 Scatena, F.N. 1990. Culvert flow in small drainages in montane tropical forests: observations from the Luquillo Experimental Forest of Puerto Rico. Tropical Hydrology and Caribbean Water Resources, American Water Resources Association, July: 237-246.

033 Scatena, F.N. 1990. Selection of riparian buffer zones in humid tropical steeplands. Pages 328-337 *in* Research Needs and applications to Reduce Erosion and Sedimentation in Tropical Steeplands, Proceedings of the Fiji Symposium, June 1990. IAHS-AISH Publ. No. 192. International Association of Hydrological Science, Institute of Hydrology, Wallingford, Oxfordshire, United Kingdom.

034 Torres, J.A. 1989. The status of the fungi-grower ants (Hymenoptera: Formicidae) in Puerto Rico and adjacent islands. Journal of Agriculture of the University of Puerto Rico 73(4):401-403.

035 Wadsworth, F.H. 1989. The forest resources network in the Caribbean. Interciencia 14(6):341-343.

036 *Weaver, P.L. and P.G. Murphy. 1990. Forest structure and productivity in Puerto Rico's Luquillo Mountains. Biotropica 22(1):69-82.

037 *Weaver, P.L. 1990. Succession in the elfin woodland of the Luquillo Mountains of Puerto Rico. Biotropica 22(1):83-89.

038 Weaver, P.L. and R.A. Birdsey. 1990. Growth of secondary forest in Puerto Rico between 1980 and 1985. Turrialba 40(1):12-22.

039 Wunderle, J.M. 1990. The effect of Hurricane Hugo on bird populations in a Puerto Rican rainforest. Page 35 *in* XVI Simposio de los Recursos Naturales, September 13-14 1990. Department of Natural Resources, San Juan, Puerto Rico. [Abstract].

B. Other publications available for distribution.
Otras publicaciones disponibles para distribución.

040 *Acevedo-Rodríguez, P. en colaboración con R.O. Woodbury. 1985. Los bejucos de Puerto Rico. Volumen I. Forest Service, General Technical Report S0-58. United States Department of Agriculture, Forest Service, Institute of Tropical Forestry, Southern Forest Experiment Station, Río Piedras, Puerto Rico. 331 p.

041 *Arendt, W.J. and J. Faaborg. 1988. Sources of variation in measurements of birds in a Puerto Rican dry forest. Journal of Field Ornithology 60(1):1-11.

042 *Arendt, W.J. and A.I. Arendt. 1988. Aspects of the breeding of the cattle egret (*Bubulcus ibis*) in Montserrat, West Indies, and its impact on nest vegetation. Colonial Waterbirds 11(1):72-84.

043 *Arendt, W.J. 1988. Range expansion of the cattle egret (*Bubulcus ibis*) in the greater Caribbean basin. Colonial Waterbirds 11(2):252-262.

044 *Barres, H. 1964. Rooting media for growing pine seedlings in hydroponic culture. Institute of Tropical Forestry Research Note No. 2. United States Department of Agriculture, Forest Service, Institute of Tropical Forestry, Río Piedras, Puerto Rico. 4 p.

045 *Birdsey, R.A. and P.L. Weaver. 1987. Forest area trends in Puerto Rico. Forest Service Research Note S0-331. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, Louisiana, USA. 5 p.

046 *Birdsey, R.A. and D. Jiménez. 1985. The forests of Toro Negro. Research Paper S0-222. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, Louisiana, USA. 29 p.

047 *Birdsey, R.A., P.L. Weaver, and C.F. Nicholls. 1986. The forest resources of St. Vincent, West Indies. Forest Service Research Paper S0-229. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, Louisiana, USA. 25 p.

048 *Bokkestijn, A. and J.K. Francis [n.d.]. *Khaya senegalensis* Juss. Dry-zone mahogany. Meliaceae, Mahogany family. SO-ITF-SM-5. United States Department of Agriculture, Forest Service,

Southern Forest Experiment Station, Institute of Tropical Forestry, Río Piedras, Puerto Rico. 4 p.

049 *Briscoe, C.B. 1962. Early lifting pine seedlings. United States Forest Service, Tropical Forest Note ITF-10. 2 p. [Available in Spanish only].

050 *Briscoe, C.B. 1962. Tree diameter growth in the dry limestone hills. United States Forest Service, Tropical Forest Note ITF-12. 2 p.

051 *Briscoe, C.B. and R.W. Nobles. 1962. Height and growth of mahogany seedlings. United States Forest Service Tropical Forest Note ITF-11. 3 p.

052 *Briscoe, C.B. and R. Ybarra-Coronado. 1971. Increasing growth of established teak. United States Forest Service, Research Note ITF-13. 7 p.

053 *Brown, S., A.E. Lugo, S. Silander, and L.H. Liegel. 1983. Research history and opportunities in the Luquillo Experimental Forest. United States Forest Service, General Technical Report S0-44. 128 p.

054 *Chudnoff, M. and T.F. Geary. 1973. On the heritability of wood density in *Swietenia macrophylla.* Turrialba 23(3):359-362.

055 *Chudnoff, M. and E. Goytia. 1967. The effect of incising on drying, treatability, and bending strength of posts. United States Forest Service, Research Paper ITF-5. 20 p.

056 *Chudnoff, M. and E. Goytia. 1972. Preservative treatments and service life of fence posts in Puerto Rico (1972 Progress Report). United States Forest Service Research Paper ITF-12. 28 p.

057 *Chudnoff, M., E.D. Maldonado, and E. Goytia. 1966. Solar drying of tropical hardwoods. United States Forest Service, Research Paper ITF-2. 26 p.

058 *Crow, T.R. and P.L. Weaver. 1977. Tree growth in a moist tropical forest of Puerto Rico. United States Forest Service Research Paper ITF-22. 17 p.

059 *Englerth, G.H. 1959. Air drying conditions for lumber in the San Juan area. United States Forest Service, Tropical Forest Research Center, Tropical Forest Note 1. 2 p.

060 *Englerth, G.H. and E.D. Maldonado. 1961. Bamboo for fence posts. United States Forest Service, Tropical Forest Research Center, Tropical Forest Note 6. [Also in Spanish in United States Forest Service, Tropical Forest Research Center, Apuntes Forestales Tropicales ITF-6].

061 *Figueroa-Colón, J.C., F.H. Wadsworth, and S. Branham, editors. Management of the Forests of Tropical America: Prospects and Technologies. Proceedings of a conference, September 22-27, 1986, San Juan, Puerto Rico. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, Río Piedras, Puerto Rico, Puerto Rico. 469 p.

062 *Figueroa, J.C., L. Totti, A.E. Lugo, and R.O. Woodbury. 1984. Structure and composition of moist coastal forests in Dorado, Puerto Rico. United States Forest Service, Research Paper S0-202. 11 p.

063 *Francis, J.K. 1989. *Pterocarpus macrocarpus* Kurz. Burma padauk, pradu. Leguminosae, Legume family. SO-ITF-SM-19. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 4 p.

064 *Francis, J.K. 1989. *Thespesia grandiflora* (DC). Urban. Maga. Malvaceae, Mallow family. SO-ITF-SM-21. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 4 p.

065 *Francis, J.K. 1989. *Bucida buceras* L. Ucar. Combretaceae, Combretum family. SO-ITF-SM-18. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 4 p.

066 *Francis, J.K. and A. Bokkestijn. [n.d.]. *Khaya nyasica* Stapf. ex Baker f. East African mahogany. Meliaceae, Mahogany family. SO-ITF-SM-9. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, Río Piedras, Puerto Rico. 4 p.

067 *Francis, J.K. 1988. *Enterolobium cyclocarpum* (Jacq.) Griseb. Guanacaste, earpod-tree. Leguminosae, Legume family. SO-ITF-SM-15. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA.

068 *Francis, J.K. 1988. Merchantable volume table for Ucar in Puerto Rico. Research Note S0-350. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, Río Piedras, Puerto Rico. 3 p.

069 *Francis, J.K. 1988. *Eucalyptus deglupta* Blume. Kamarere. Myrtaceae, Myrtle family. SO-ITF-SM-16. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, New Orleans, Louisiana, USA. 5 p.

070 *Francis, J.K. [n.d.]. *Agathis robusta* (C. Moore ex F. Muell) F.M. Bailey. Queensland kauri. Araucariacae, Araucaria family. SO-ITF-SM-10. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, Río Piedras, Puerto Rico. 5 p.

071 *Francis, J.K. [n.d.]. *Araucaria heterophylla* (Salisb.) Franco. Norfolk-island pine. Araucariaceae, Araucaria family. SO-ITF-SM-11. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, Río Piedras, Puerto Rico. 3 p.

072 *Francis, J.K. [n.d.]. *Hernandia sonora* L. Mago, toporite. Hernandiaceae, Hernandia family. SO-ITF-SM-13. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, Río Piedras, Puerto Rico. 3 p.

073 *Francis, J.K. [n.d.]. *Terminalia ivorensis* (A. Chev.) Idigbo, Emire. Combretaceae, Combretum family. SO-ITF-SM-12. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, Río Piedras, Puerto Rico. 5 p.

074 *Francis, J.K. [n.d.]. *Maesopsis eminii* Engl. Musizi. Rhamnaceae, Buckthorn family. SO-ITF-SM-8. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, Río Piedras, Puerto Rico. 4 p.

075 *Frangi, J.L. and A.E. Lugo. Ecosystem dynamics of a subtropical floodplain forest. Ecological Monographs 55:351-369.

076 *Jiménez, J.A. 1985. *Rhizophora mangle* L.-Red mangrove. SO-ITF-SM-2. United States Department of Agriculture, Forest Service, Institute of Tropical Forestry, Southern Forest Experiment Station, New Orleans, Louisiana, USA. 7 p.

077 *Jiménez, J.A. 1985. *Laguncularia racemosa* (L.) Gaertn. f. White mangrove. SO-ITF-SM-3. United Stated Department of Agriculture, Forest Service, Institute of Tropical Forestry, Southern Forest Experiment Station, New Orleans, Louisiana, USA. 4 p.

078 *Jiménez, J.A. and A.E. Lugo. 1985. *Avicennia germinans* (L.) L. Black mangrove. SO-ITF-SM-4. United States Department of Agriculture, Forest Service, Institute of Tropical Forestry, Southern Forest Experiment Station, New Orleans, Louisiana, USA. 6 p.

079 *Ledig, F.T. and J.L. Whitmore. 1981. The calculation of selection differential and selection intensity to predict gain in a tree improvement program for plantation grown Honduras pine in Puerto Rico. United States Forest Service Research Paper S0-170. 7 p.

080 *Liegel, L.H. 1985. Growth, form, and flowering of Caribbean pine families in Puerto Rico. Commonwealth Forestry Review 64(1):67-74.

081 *Liegel, L.H. 1984. Results of 5- to 6-year old provenance trials of *Pinus oocarpa* Schiede on eight sites in Puerto Rico. Silvae Genetica 33(6):223-230.

082 *Liegel, L.H. 1984. Status, growth, and development of unthinned Honduras pine plantations in Puerto Rico. Turrialba 34(3):313-324.

083 *Liegel, L.H. 1984. Assessment of hurricane rain/wind damage in *Pinus caribaea* and *Pinus oocarpa* provenance trials in Puerto Rico. Commonwealth Forestry Review 63(1):47-53.

084 *Liegel, L.H. and C.R. Venator. 1987. A technical guide for forest nursery management in the Caribbean and Latin America. General Technical Report S0-67. United States Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, Louisiana, USA. 156 p.

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Versión en Español

INVESTIGACIÓN DE PLANTACIONES FORESTALES

John K. Francis
Investigador Forestal

El género *Eucalyptus* contiene más de 500 especies nativas de Australia y una que procede de las grandes islas al norte de este continente. Los eucaliptos son valorados como especie de plantación de madera útil, de crecimiento extraordinario, resistentes a la sequía y de mínimo requerimiento de nutrientes. Más de 30 especies se han probado en Puerto Rico. Aunque la mayoría murieron por completo en los primeros años, algunas especies con buen crecimiento han permanecido.

Eucalyptus robusta lleva 60 años aquí y ha rendido más consistentemente que todas las demás especies probadas. Crece mejor en ambientes húmedos o muy húmedos con suelos profundos y ácidos. Areas grandes de plantaciones se encuentran en los bosques estatales de Toro Negro, Carite y Monte Guilarte. "Robusta" produce de 10 hasta 30 m^3/ha anualmente, dependiendo del sitio y edad de la plantación. Desafortunadamente la madera es dura y seca con muchos defectos. Postes redondos de verja y aserrado son los productos más importantes actualmente en Puerto Rico.

Eucalyptus deglupta es el único eucalipto que no es australiano. Procede de Indonesia, Nueva Guinea y las Filipinas. "Deglupta" se desarrolla mejor en suelos fértiles, en áreas húmedas y de elevación baja. Plantaciones jóvenes en Puerto Rico han rendido de 10 hasta 30 m^3/ha anualmente. Probablemente un crecimiento mayor es posible en suelos aluviales de textura mediana. Tres árboles de 10 años de edad, creciendo en pleno sol en el recinto del Instituto, han añadido un promedio de 6 cm de diámetro por año. "Deglupta" produce una hermosa y laborable madera que hasta el momento no se ha cosechado en Puerto Rico. Este árbol se planta como especie ornamental por causa de su corteza multicolor. Dos publicaciones recientes (Francis 1988, Lugo y Francis 1990) describen esta especie.

Otras especies que han sobrevivido aceptablemente y han demostrado buen crecimiento en pruebas a largo plazo son *E. grandis, E. citriadora, E. resinifera, E. torelliana, E. acmenoides, E. urophylla* y dos híbridos. No se puede determinar ahora si en Puerto Rico se sembrarán eucaliptos en cantidades significativas para producción de madera. Lo cierto es, que en sitios aceptables, ciertos eucaliptos son muy productivos plantados en Puerto Rico.

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MANUAL DE SILVICULTURA TROPICAL

John K. Francis
Investigador Forestal

Durante los últimos años hemos estado trabajando en un manual de silvicultura de árboles tropicales. Este manual es similar al que ha publicado el Servicio Forestal de los Estados Unidos para especies de zonas templadas. Para cada especie se prepara una monografía con toda la información disponible. Todas las monografías contienen el mismo formato y los tópicos incluyen la historia de vida de la especies, su crecimiento, los sistemas de manejo y los usos. En muchos ejemplos los autores coleccionan y reportan datos originales para suplementar la información bibliográfica. Además, las monografías contienen mapas de distribución de la especie y una foto del árbol en etapa madura. Cada trabajo se publica independientemente en un formato con argollas para facilitar su colección en libretas. Al presente se han publicado monografías para 34 especies y hay alrededor de 25 especies adicionales en preparación. Otras 20 especies de árboles tropicales han sido incluídas en la nueva edición del manual de silvicultura que pronto publicará el Servicio Forestal de los Estados Unidos. Nuestra intención es recoger en un solo volumen todas las monografías de especies tropicales. Además queremos, eventualmente, traducir el volumen al español. La tabla que sigue contiene una lista de las monografías ya publicadas con sus autores. Copias de cualquiera se pueden conseguir en el Instituto de Dasonomía Tropical.

Especie	Autor	Número de publicación
Anthocephalus chinensis	A.E. Lugo y J. Figueroa	SO-ITF-SM-01
Rhizophora mangle	J.A. Jiménez	SO-ITF-SM-02
Laguncularia racemosa	J.A. Jiménez	SO-ITF-SM-03
Avicennia germinans	J.A. Jiménez y A.E. Lugo	SO-ITF-SM-04
Khaya senegalensis	A. Bokkestijn y J.K. Francis	SO-ITF-SM-05
Albizia procera	J.A. Parrotta	SO-ITF-SM-06
Albizia lebbek	J.A. Parrotta	SO-ITF-SM-07
Maesopsis eminii	J.K. Francis	SO-ITF-SM-08
Khaya nyasica	J.K. Francis y A. Bokkestijn	SO-ITF-SM-09
Agathis robusta	J.K. Francis	SO-ITF-SM-10
Araucaria heterophylla	J.K. Francis	SO-ITF-SM-11
Terminalia ivorensis	J.K. Francis	SO-ITF-SM-12
Hernandia sonora	J.K. Francis	SO-ITF-SM-13
Hibiscus elatus	P.L. Weaver y J.K. Francis	SO-ITF-SM-14
Enterolobium cyclocarpum	J.K. Francis	SO-ITF-SM-15
Eucalyptus deglupta	J.K. Francis	SO-ITF-SM-16
Guarea guidonia	P.L. Weaver	SO-ITF-SM-17
Bucida buceras	J.K. Francis	SO-ITF-SM-18

Especie	Autor	Número de publicación
Pterocarpus macrocarpus	J.K. Francis	SO-ITF-SM-19
Andira inermis	P.L. Weaver	SO-ITF-SM-20
Thespesia grandiflora	J.K. Francis	SO-ITF-SM-21
Mammea americana	J.K. Francis	SO-ITF-SM-22
Terminalia catappa	J.K. Francis	SO-ITF-SM-23
Dalbergia sissoo	J.A. Parrotta	SO-ITF-SM-24
Tabebuia donell-smithii	J.K. Francis	SO-ITF-SM-25
Syzygium jambos	J.K. Francis	SO-ITF-SM-26
Hymenaea courbaril	J.K. Francis	SO-ITF-SM-27
Fraxinus uhdei	J.K .Francis	SO-ITF-SM-28
Ceiba pentandra	J.D. Chinea	SO-ITF-SM-29
Tamarindus indica	J.A. Parrotta	SO-ITF-SM-30
Paraserianthes falcataria	J.A. Parrotta	SO-ITF-SM-31
Spathodea campanulata	J.K. Francis	SO-ITF-SM-32
Senna siamea	J.A. Parrotta y J.K. Francis	SO-ITF-SM-33
Citharexylum fruticosum	J.K. Francis	SO-ITF-SM-34

INVESTIGACION Y MANEJO FORESTAL

Peter L. Weaver
Dasónomo

Bosques Naturales

El bosque de tabonuco (bosque montano bajo pluvial *sensu* Beard; bosque subtropical muy húmedo o pluvial *sensu* Holdridge) se encuentra entre los 150 y 600 m de elevación en el Bosque Experimental de Luquillo; el bosque colorado (bosque montano pluvial *sensu* Beard; bosque montano bajo muy húmedo o pluvial *sensu* Holdridge) está situado entre los 600 y 900 m de elevación; y el bosque enano (bosque enano *sensu* Beard; una asociación atmosférica en el bosque montano bajo muy húmedo o pluvial *sensu* Holdridge) está situado entre los 900 m y los 1050 m de elevación en la cumbre de la Sierra de Luquillo. Los bosques colorado y enano son bosques nublados. Estudios de la dinámica forestal comenzados temprano en los 1980's demostraron que los bosques nublados de montañas tropicales fueron bajos en productividad y lentos para recuperarse después de disturbios.

Se estimó que la producción neta primaria en el bosque de colorado fue 7.60 Mg/ha.año (Weaver y Murphy 1990) por medio de la suma de la caída de hojarasca (6.80 Mg/ha.año), el aumento de biomasa sobre el terreno (0.59 Mg/ha.año) y herbivoraria (0.21 Mg/ha.año). El índice de área foliar (árboles, epífitas y vegetación) fue aproximadamente 5 m^2/m^2, y el volumen y biomasa sobre el terreno, 220 m^3/ha y 130 Mg/ha, respectivamente. Se estimó la herbivoraria en 5.1 porciento y la tasa de herbivoraria en 4.0 porciento por año. El promedio de hojarasca en pie fue 6.0 Mg/ha con la tasa de descomposición de unas 0.78 veces por año.

Se compararon las características de estructura y dinámica de los bosques tabonuco, colorado y enano sobre un gradiente de 600 m. De las características estructurales estudiadas, el número de árboles por hectárea, el área basal y la materia orgánica del suelo se aumentaron con elevación. En contraste, el área específica de las hojas, la altura de la copa, el rango de diámetros de los árboles, el volumen y biomasa del bosque, el índice de área foliar, y la diversidad de especies disminuyeron. De las características dinámicas estudiadas, el reclutamiento y la mortalidad de los árboles, el crecimiento de árboles (crecimiento en diámetro, volumen, y biomasa), la caída de hojarasca, la hojarasca en pie, la herbivoraria y la tasa de herbivoraria, la tasa de descomposición de la hojarasca, la producción maderera y la producción primaria neta sobre el terreno, todos disminuyeron con un aumento en elevación.

En diciembre de 1968, se estrelló un avión en el bosque enano cerca de Pico del Este. Durante los primeros seis años, la regeneración en el predio donde se estrelló el avión fue principalmente por helechos y gramíneas. Una visita al lugar 18 años después, reveló que numerosas especies arborescentes invadieron el lugar. Se condujo otro estudio y se registraron 23 especies arborescentes (Weaver 1990). De los aproximadamente 1200 tallos arborescentes que se registraron, tres-cuartos fueron especies primarias del bosque enano. La biomasa total sobre el terreno promedió 7.76 Mg/m^2 y se clasificó así: dicotiledonas arborescentes, 30 porciento; palmas, 13 porciento; helechos, 31 porciento; y gramíneas y herbáceas, 26 porciento. La recuperación de biomasa sobre el terreno, después de 18 años, apareció lineal y, según la

tasa observada, demoraría alrededor de dos siglos para que el sitio volviera a su biomasa original.

Propuesta para Siembras en Línea

Siembras en línea, a veces llamadas siembras lineales de conversión, es una técnica de reforestación que se ha utilizado con éxito variable en los trópicos para mejorar el potencial productivo de bosques secundarios degradados. Se colocan líneas paralelas de aproximadamente 3 m de ancho en las cuales se siembran plántulas espaciadas 2.5 m entre ellas (aproximadamente 365 plántulas por hectárea). Se interplantan, entonces, valiosas especies tropicales de crecimiento rápido en los bosques secundarios. Después de 20 años más o menos, con técnicas apropiadas, se produce un bosque cerrado.

Comenzando a mediados de los 1960's, científicos del Instituto de Dasonomía Tropical experimentaron con caoba sembrada en líneas dentro del Bosque Experimental de Luquillo. Hasta la fecha la técnica ha rendido resultados satisfactorios y, basado en ese éxito, se desarrolló un plan para trasladar la tecnología. Tentativamente se escogió Guatemala, República Dominicana y Grenada para cooperar con Puerto Rico en el desarrollo de plantaciones de caoba sembrada en línea. El plan para trasladar la tecnología, aprobado en julio de 1990, envuelve la planificación cooperativa, selección de sitios, producción en el vivero y la siembra en el campo. Se han identificado los cooperadores potenciales dentro de los países respectivos y tentativamente se han seleccionado sitios adecuados. La naturaleza internacional del plan propuesto demanda cooperación estrecha entre las entidades envueltas en el programa.

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ESTUDIOS ECOLOGICOS

Ariel E. Lugo
Ecólogo

Este año colaboré con cuatro colegas y publicamos cinco trabajos en los siguientes tópicos: bosques secundarios (Brown y Lugo 1990a), sistemas pantanosos caribeños (Lugo y Brown 1988), contenido de carbono y nitrógeno en suelos (Brown y Lugo 1990b), producción de biomasa en plantaciones (Lugo, Wang y Bormann 1990) y métodos para estimar la biomasa de bosques partiendo de datos sobre volumen (Brown, Gillespie y Lugo 1989).

Bosques Secundarios

Definimos bosques secundarios como aquellos que resultan de disturbios naturales o humanos, como por ejemplo, los que sufren extracción de madera o crecen luego del abandono de la agricultura. Revisamos la literatura sobres estos sistemas para averiguar el área de estos bosques, la velocidad de formación de ellos, sus características ecológicas, valores y usos por los humanos y su potencial de manejo. Los bosques secundarios son abundantes en el trópico, representan el 40% del área total de bosques y se producen a una velocidad de 9 millones de hectáreas por año. Hay importantes diferencias geográficas en el área, velocidad de formación y tipo de bosque secundario tropical.

Los bosques secundarios aparentan acumular especies leñosas relativamente rápido pero los mecanismos que explican el fenómeno son complejos y no hay patrones definidos. En comparación a vegetación madura, los bosques secundarios son simples, aunque la edad, clima y tipo de suelo modifican la comparación. La acumulación de biomasa es rápida en bosques secundarios (hasta 100 t ha^{-1} durante los primeros 15 años), pero el historial de disturbio modifica la tendencia. La producción de hojarasca también es rápida, hasta 12-13 t ha^{-1} yr^{-1} a los 12-15 años de edad. En bosques secundarios muy jóvenes (<20 años), la producción de hojarasca es más alta que la producción de madera y por lo tanto domina la producción primaria neta del sistema. Más material orgánico se produce y transfiere al suelo en bosque secundario joven que lo que se almacena en la fracción aérea de la vegetación. El impacto sobre el almacenaje de materia orgánica del suelo es importante y explica por qué la acumulación de materia orgánica en el suelo de bosques secundarios es rápida y se recobra generalmente en 50 años. Los nutrientes se acumulan rápidamente en la vegetación secundaria y retornan rápidamente al suelo donde están disponibles para el reciclaje por medio de raíces.

Propusimos un modelo sobre las ganancias, pérdidas, rendimientos, costos, beneficios y alternativas de los cambios en uso de terreno en los trópicos (Fig. 1, página 7). La sociedad pierde valores y servicios si la conversión de tierras forestales a bosque secundario y uso agrícola es muy rápida, o si obvian etapas en la cadena de conversión. Para evitar esas pérdidas sugerimos el uso y manejo de bosques secundarios desde una perspectiva global, tomando en consideración todo el paisaje de una región. Esto es posible en los trópicos porque los proyectos de desarrollo son generalmente grandes.

Sistemas Pantanosos del Caribe

El área de sistemas pantanosos particulares en las islas del Caribe es generalmente pequeña, pero en las islas grandes existen sistemas

pantanosos muy grandes. Por ejemplo, Cuba tiene un complejo pantanoso de 5 millones de hectáreas. Los sistemas pantanosos de la región son muy diversos y aparentemente predominan los sistemas boscosos pantanosos sobre los sistemas pantanosos dominados por herbáceas. Desconocemos el área total de sistemas pantanosos en el Caribe pero sabemos que tradicionalmente las deficinones en uso ignoran los sistemas pantanosos montanos en lugares con lluvias en exceso de 3,500 mm, con suelos poco profundos y arcillosos. Estos están generalmente saturados y las condiciones favorecen el establecimiento de especies de sistemas pantanosos. Describimos estos sistemas en detalle.

Los sistemas pantanosos del Caribe se caracterizan por la abundancia de sistemas lotícos, ausencia de sistemas de agua salada dominados por herbáceas, ausencia de sistemas pantanosos en las márgenes de lagos, alta riqueza de especies, abundancia de palmeras, y altas tasas de productividad primaria. La diversidad de climas tropicales y subtropicales, topografía variada, geología diversa y las condiciones edáficas son los factores principales que contribuyen a la diversidad y productividad de los sistemas pantanosos caribeños. Las características estructurales y funcionales de sistemas ribereños, de cuenca y de borde en el Carib,e se compararon con las del resto del mundo para demostrar que las del Caribe son distintas (Tablas 1 y 2, páginas 8 y 9). Los huracanes, el efecto del mar, el clima tropical y la complejidad biótica explican las diferencias. El tamaño reducido de los sistemas pantanosos de las islas los hacen vulnerables a desarrollos no planificados y al azar se pierde el efecto de amortiguamiento característico de sistemas con áreas mucho más grandes, se reduce el márgen de error en la planificación y manejo de los sistemas, y aumenta el valor por unidad de área del sistema.

Contenido de Carbono y Nitrógeno en el Suelo

Coleccionamos suelos de bosques maduros y secundarios y de zonas agrícolas en tres zonas de vida subtropicales en Puerto Rico y las Islas Vírgenes de los Estados Unidos. El objetivo era determinar los efectos de la conversión de bosques a usos agrícolas y vice versa en la acumulación de carbono (C) y nitrógeno (N) en el suelo. Controlamos al máximo los otros factores que afectan la acumulación de C y N en el suelo o sea pendiente, elevación, aspecto, y textura. El contenido de C (a una profundidad de 50 cm o hasta la roca) en sitios bajo cultivo (expresado en porciento del bosque maduro) era más bajo en clima muy húmedo (44%) y húmedo (31%) que en clima seco (86%) mientras que el contenido de N era alto irrespectivo del clima (60-130%). La conversión de bosque a pastizal resultó en menos pérdida de C y N que la conversión a cultivos. El tiempo que tardaba la recuperación de C y N durante la sucesión fue igual en las tres zonas de vida (40-50 años para C y 15-20 años para N). Sin embargo, la velocidad de recuperación del C fue más rápida en el clima muy húmedo mientras que el N se recuperó más rápidamente en la zona seca. Presentamos además evidencia de pérdida y ganancia de C a profundidades de 50-100 cm.

Producción de Biomasa en Plantaciones

Manejamos rodales de *Casuarina equisetifolia, Albizia procera, Eucalyptus robusta*, y dos variedades de *Leucanena luecocephala* (una exótica y otra nativa) para producción máxima de biomasa en el mismo clima (1102 mm de lluvia y 25 C de temperatura promedio anual) y condiciones edáficas en el Valle de Lajas de Puerto Rico (Lat. 18°N, Long. 67°O). El manejo fue intensivo durante las etapas de establecimiento y crecimiento inicial. Las tasas de producción de tallos y ramas grandes

(> 2.5 cm de diámetro) a los 5.5 años de edad fueron 27.8, 20.4, 10.1, 7.7 y 5.5 t $ha^{-1}año^{-1}$ para *Casuarina, Albizia, Eucalyptus, Leucaena* exótica y la nativa, respectivamente. La producción de tallos de 40 plantaciones establecidas con los mismos propósitos en otras partes del mundo promedió 7.9 t $ha^{-1}año^{-1}$. La secuencia de las especies en términos de producción de biomasa aérea total y acumulación de hojarasca siguió el mismo orden. A la edad de 5.5 años la acumulación de hojarasca en plantaciones de las distintas especies (en el mismo orden) fue de 16.2, 10.2, 11.8, 7.0, y 6.5 t ha^{-1}. Treinta y cinco bosques tropicales promediaron 6 t ha^{-1}. El manejo intensivo en suelos fértiles aumenta el rendimiento de biomasa en plantaciones pero no todas las especies responden igual.

Estimados de Biomasa a Base de Volumen

Desarrollamos una estrategia para estimar la biomasa aérea de bosques tropicales. Desarrollamos regresiones para estimar la biomasa aérea de árboles individuales en función al diámetro a la altura del pecho, altura total, densidad de la madera y la zona de vida de acuerdo a Holdridge (Tabla 3, página 10). Con el propósito de estimar la biomasa aérea comercial y total por unidad de área y tipo de bosque y para estimar un factor de expansión de biomasa total a comercial, aplicamos las regresiones a 5,300 árboles en 43 rodales independientes y 101 tablas de rodales basadas en grandes inventarios en cuatro países. El diámetro cuadrático de un rodal (QSD), definido como el diámetro del arbol con un área basal promedio, afecta la magnitud del factor de expansión. Rodales con árboles pequeños tienen factores de expansión altos (hasta 6.4) y a medida que QSD aumenta, el factor de expansión disminuye a un valor constante (como 1.75). Obtuvimos factores de expansión de 1.75, 1.9, y 2.0, respectivamente, para bosques clasificados por la FAO como maduros, intervenidos, y no-productivos. Utilizando estos factores a los datos de volumen de la FAO, encontramos que la biomasa en los bosques tropicales era de 28 a 47 % más alta que valores estimados anteriormente con los mismos datos de volumen (Tabla 4, página 11). Sin embargo, estimados de biomasa de bosques tropicales basados en tumba y peso de árboles en pequeñas parcelas, continúan dando valores mucho más altos que los valores derivados de inventarios de volumen.

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INVESTIGACION DE VIDA SILVESTRE

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Durante el año fiscal 1990 un nuevo proyecto fue iniciado, dos fueron continuados y una corta evaluación ambiental fue completada, todo lo cual se resume a continuación. Además evalué un libro para la revista Journal of Field Ornithology (Wunderle 1990).

El Efecto del Huracán Hugo en la Población de Aves del Bosque Experimental de Luquillo

El Huracán Hugo causó daño substancial al dosel y al sotobosque del área de tabonuco del Bosque Experimental de Luquillo. Dos semanas luego del paso del huracán la razón total de captura de aves en redes fue mayor que en el estudio anterior que sirve de base a éste, debido al aumento en la captura de especies que eran típicas del dosel y raras en el sotobosque. Los nectarívoros fueron los únicos que no mostraron cambio o que decrecieron durante el primer período de muestreo con redes. Sin embargo, luego de varios meses, algunas especies del dosel y del sotobosque declinaron drásticamente, otras aumentaron y otras variaron grandemente. La vegetación en los claros dentro del bosque antes del huracán fue la primera en recuperarse y producir frutos, atrayendo grandes cantidades de aves entre los 3 y 4 meses luego del paso del huracán. El huracán, en sí mismo, es probable que no mató muchos pájaros directamente, pero su mayor impacto fue en retrasar la sucesión de plantas y así tener un efecto a largo alcance sobre la comunidad de aves en el bosque que continuaremos investigando.

Estudio Fenológico de Plantas que Producen Frutos y Semillas Usadas por la Cotorra Puertorriqueña en el Bosque de Palo Colorado

La continuación de este estudio basado en tres veredas fenológicas con aproximadamente 100 árboles y bejucos marcados en cada una ya está en su cuarto año. Este estudio ha sido beneficioso para evaluar el impacto del Huracán Hugo sobre las fuentes tradicionales de comida de la cotorra y su recuperación .

Uso del Hábitat y Biología Poblacional de la Reinita Azul Invernando en Puerto Rico

Recientemente los biólogos se han interesado en la suerte de las aves migratorias de Norteamérica que invernan en los trópicos. A la luz de esta preocupación, he continuado estudiando a la Reinita Azul, una especie indicadora del Bosque Experimental de Luquillo. Hasta ahora he completado la investigación durante el segundo invierno sobre el uso del hábitat y la biología poblacional. He demostrado una segregación sexual del hábitat, mientras que los resultados con anillas de colores y demarcación de territorios en tres áreas de estudio indican ecologías poblacionales muy diferentes en áreas diferentes (por ejemplo, estabilidad territorial, solapamiento, individuos flotantes, dieta y razón de edades). Estos estudios nos ayudarán a entender mejor la supervivencia de esta especie durante su invernación en los bosques caribeños.

Análisis Ambiental del Proyecto de Pequeñas Granjas Cafetales

Algunas de las nuevas variedades de café requieren menos sombra, por lo tanto, es posible que la remoción de estos árboles proveyendo esta sombra en las plantaciones tenga un efecto negativo en el medio ambiente. Para evaluar el efecto ambiental de estas nuevas técnicas de cultivo de café con sombra reducida, un reporte técnico fue escrito para la Agencia de Desarrollo Ambiental de los Estados Unidos en Guatemala (Wunderle et al. 1990). Serví de líder de un equipo evaluador de tres miembros y también examiné el impacto ambiental de la reducción de sombra sobre la diversidad biológica.

Las aves se utilizaron para obtener una medida relativa de la biodiversidad y para examinar el uso de los cafetales y de los árboles que les proveen sombra para alimento en las plantaciones de café de altura en Guatemala. Como grupo, los pájaros son idóneos para este propósito porque son relativamente fácil de observar e identificar y no requieren técnicas de colección complicadas para documentar su presencia y así pueden ser muestreados durante un proyecto de corta duración. También proveen una indicación relativa de la salud del medio ambiente en relación al uso de pesticidas. Un análisis preliminar de las localidades donde los pájaros se alimentan indica que el 57% de las especies se alimentan en el dosel a ser removido (N=25); 18% en el dosel y en el cafetal (N=8); 9% en el cafetal (N=4) y 16% en el piso (N=7), (Fig. 1, página 14). Ocho especies de aves migratorias norteamericanas fueron observadas alimentándose en la copa de los árboles y una de ellas también se alimentaba en los árboles de café. Ninguno de estos migratorios se alimentaba exclusivamente en las plantas de café. Cuatro especies residentes fueron observadas anidando en el dosel y ninguna anidando en el café.

Concluyo que los árboles que proveen sombra son responsables de la mayoría de la diversidad en aves que se encuentra en las plantaciones de café. Es posible que patrones similares se encuentren en otro número de animales, indicando que los árboles de sombra juegan un papel crítico manteniendo la diversidad animal en las plantaciones de café. Aún más, muchos de estos árboles estaban cubiertos con epífitas (bromelias y orquídeas, por ejemplo), lo que sugiere también un papel importante manteniendo parte de la diversidad vegetal en estas plantaciones. También concluyo, como lo han hecho otros, que la cubierta del dosel en las plantaciones de café puede servir de refugio a los habitantes del bosque en áreas sufriendo deforestación. Por lo tanto, una remoción generalizada de los árboles de sombra en las plantaciones de café contribuirá a la pérdida de la diversidad biológica.

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OTRAS INVESTIGACIONES

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Efectos a Corto Plazo del Huracán Hugo en Comunidades de Aves Forrajeras del Bosque Experimental de Luquillo (BEL)

Para complementar los estudios que se están realizando en las poblaciones de aves del bosque de tabonuco, se hicieron censos luego del Huracán Hugo en rutas establecidas en los bosques de palo colorado, enano y en una plantación de varias especies de árboles. Aunque la destrucción del habitat por parte del huracán fue dispersa, tanto dentro como entre los diferentes tipos de bosque, las poblaciones de aves dentro de cada comunidad respondieron de manera similar en los tres tipos de bosque.

Aves "Tramps"

En esta categoría se consideran aquellas especies de aves que poseen una gran habilidad colonizadora y que son generalistas en la mayoría de sus requisitos (ej., hábitat y dieta). En el BEL, el Zorzal Pardo, la Reinita Común y el Zorzal de Patas Coloradas son los principales ejemplos de aves "tramps". Ambas especies de zorzales son omnívoros, mientras que la Reinita Común es nectarívora, aunque puede alimentarse de insectos cuando las fuentes de néctar desaparecen. Cada especie tiene una temporada de apareamiento extensa, con posturas múltiples cada año. En Puerto Rico, el Zorzal Pardo y la Reinita Común se encuentran desde la costa hasta los picos más altos. Sin embargo, en el BEL el primero es más común en el bosque de palo colorado, mientras que el segundo es común en los tres tipos de bosque. El Zorzal de Patas Coloradas es común en áreas abiertas y en el borde de los bosques, por lo que es bien abundante en la plantación de diversas especies de árboles en el BEL. Dos días después del paso del Huracán Hugo, cada especie fue abundante en su habitat preferido, aprovechándose de las frutas caídas o de la exposición de presas tales como insectos, coquís y lagartijos, (Fig. 1, página 16). A diferencia de otras especies de aves frugívoras y nectarívoras en el BEL, las poblaciones de estas tres especies "tramps" permanecieron estables y aumentaron substancialmente durante el primer año después del huracán.

Aves Frugívoras y Nectarívoras

Las poblaciones de muchas especies de aves frugívoras y nectarívoras permanecieron bajas en los primeros cinco y seis meses después del disturbio (Figs. 2 y 3, páginas 17 y 18), experimentando un aumento en marzo y abril. La mayor abundancia de éstas se observó durante los meses de mayo y junio, lo cual estuvo influenciado por la cantidad de machos cantando (y a que muchas especies de aves intentan anidar en estos meses). El estudio de estas aves continúa con el propósito de determinar si las poblaciones de aves frugívoras se recuperan.

Aves Insectívoras

A diferencia de las aves frugívoras y nectarívoras que dependen de los ciclos reproductivos de la vegetación, las poblaciones de muchas aves insectívoras permanecieron estables durante el primer año después del disturbio (Fig. 4, página 19). Posterior al Huracán Hugo, las poblaciones de insectos aumentaron en respuesta a una recuperación de la vegetación. En el bosque de palo colorado, las poblaciones de Reinita sufrieron una aparente disminución, lo cual pudo deberse a que los machos estuvieron

cantando en los meses de septiembre y octubre pero no en diciembre.

Reinitas Migratorias de América del Norte

Después del huracán, las aves migratorias fueron poco abundantes en los tres tipos de bosque (Fig. 5, página 21). El rastreo de estas poblaciones continúa para determinar el status de cada especie.

Efecto del Huracán Hugo en la reproducción del Zorzal Pardo y del Zorzal de Patas Coloradas

Se estudiaron ambas especies con el objetivo de determinar el efecto del Huracán Hugo en sus ciclos reproductivos. Durante diez temporadas reproductivas previas al huracán (1979-1988), el Zorzal Pardo anidó entre noviembre y agosto, con una mayor incidencia entre enero y agosto. Por lo general, las hembras tienen de dos a tres camadas por temporada (sin incluir reemplazos). En el 1987, por ejemplo, la temporada se extendió desde diciembre hasta agosto. En este año, un total de 38 hembras realizaron 100 anidamientos, para un promedio de 2.63 anidamientos por hembra. En contraste, durante el 1990 (temporada posterior al paso del Huracán Hugo), 42 hembras anidaron en solo 53 ocasiones para un promedio de 1.26 anidamientos por hembra (significativamente más bajo que en años previos al huracán; alfa = 0.05, $P < 0.06$, Prueba Kruskal Wallis en una dirección con análisis por rangos). La temporada reproductiva del 1990 estuvo restringida a un período de 2.5 meses (mayo y comienzos de julio), con el mayor número de anidamientos en el mes de junio. Inesperadamente, la segunda temporada reproductiva después del huracán (1991) comenzó en septiembre de 1990. Más de la mitad de las hembras habían puesto antes de terminar el mes de diciembre, mientras que algunas habían logrado que sus pichones volaran y tuvieron su segunda postura en ese mismo período de tiempo.

Por otra parte, el Zorzal de Patas Coloradas tuvo un período de anidamiento entre febrero a julio en las temporadas previas al Huracán Hugo (1985-1987). Esta especie, de manera similar al Zorzal Pardo, pospuso su apareamiento hasta fines de abril. En este primer intento reproductivo sólo una de diez parejas estudiadas anidó exitosamente. En los meses de mayo a junio anidaron cuatro parejas, de las cuales solo dos lograron pichones. La reducción en el número de posturas se observó en los nidos de todos los zorzales de patas coloradas y en algunos del Zorzal Pardo, lo cual se debió posiblemente a la escasez de alimento.

Efecto del Huracán Hugo en las poblaciones de la Calandria de Monserrate, otra ave de bosque, y en su hábitat

En respuesta a un pedido hecho por la Fundación Mundial de Vida Silvestre, el Centro RARE y el Gobierno de Monserrate, se estudió el efecto del Huracán Hugo sobre las poblaciones de la Calandria de Monserrate (especie endémica) y de otras aves de los bosques. La isla fue visitada seis meses después que el huracán destruyera la mayoría de sus bosques. Durante dos semanas de estudio, se observaron más de 100 individuos, lo cual indica que la especie no se encuentra en peligro inmediato (ver Arendt, 1990 para detalles). Luego del huracán, la Calandria de Monserrate emigró desde los bosques enanos (severamente destruídos) hacia las pendientes superiores en South Soufriere Hills. Se observaron grandes concentraciones de calandrias en franjas de bosque en regeneración (400-700 m sobre el nivel del mar) y en arroyos dispersos a través de las montañas del interior de la isla. Las calandrias se aparearon en marzo y se confirmó su reproducción luego del huracán, cuando se observó a una pareja

alimentando a dos pichones que volaron recientemente del nido.

Además de la calandria, se realizaron 90 censos tipo puntos de conteo en áreas boscosas de las tres principales montañas del interior de la isla. En éstos censos se detectó un total de 619 individuos, agrupados en 15 especies. A excepción del Zumbador de Pecho Azul (especie nectarívora) ninguna otra especie resultó afectada por el paso del huracán, aunque todavía es muy temprano para observar disminuciones poblacionales como resultado de escasez de alimento, áreas de forrajeo y anidaje, etc.

El impacto del Huracán Hugo en los bosques de Monserrate fue severo. La mayoría de los árboles de bosque en las tres principales montañas del interior de la isla sufrieron daños en sus ramas primarias, aunque permanecieron erguidos (52% de los árboles muestreados en el bosque montano). Sin embargo, el bosque enano de las pendientes superiores de South Soufriere Hills recibió el mayor daño, donde el 63% de los árboles muestreados cayeron al suelo con sus raíces fuera del terreno.

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IMPACTO DEL HURACAN HUGO EN LA COTORRA PUERTORRIQUENA Y LOS ESFUERZOS INTERAGENCIALES EN SU RECUPERACION

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Abundancia de Cotorras

Población Silvestre

La escasa población de la cotorra puertorriqueña que habita en la Sierra de Luquillo había aumentado de 13 aves en el 1975 a 47 individuos luego de la de la temporada reproductiva del 1989, o sea, que su abundancia se cuadruplicó en un período de 14 años. Sin embargo, hubo un promedio de 30 cotorras en el período de 1984-1989, en conteos totales hechos en la temporada previa a la reproducción (estimado más real de la población), lo que sugiere que la población fue mayor al doble que en el 1975. Desafortunadamente, el disturbio y daño físico causado por el Huracán Hugo el 18 de septiembre de 1989 al área de las cotorras resultó en la pérdida de entre una tercera parte a casi la mitad de la población. Luego del huracán y hasta noviembre de 1990 el número de cotorras alcanzó el 50% del total que habían en el período post-reproductivo previo al huracán, lo cual se debió en parte al pobre esfuerzo reproductivo en la temporada reproductiva del 1990 (Fig. 1, página 23).

Población Cautiva

Previo al Huracán Hugo, habían 52 cotorras cautivas en el Aviario de Luquillo. Ahora hay 57 individuos como resultado de la producción de cinco pichones por dos parejas reproductivas durante la temporada de 1990.

Esfuerzos Reproductivos Luego del Huracán Hugo

La reproducción de la cotorra se extiende normalmente desde enero hasta julio. Luego del huracán, la temporada reproductiva se detuvo de 2 a 3 meses, una tendecia que se observó también en otras especies de aves. La mayoría de las actividades reproductivas ocurrieron de abril a junio, período en el cual no se efectuaron conteos poblacionales (Fig. 1, página 23). Solamente se confirmaron tres intentos reproductivos durante la temporada reproductiva del 1990, aunque a comienzos de esta se observó a una cuarta pareja demostrando señales de querer anidar. Hubo intentos individuales de anidar por parejas tradicionales en *South Fork* 1 y 2 y posiblemente por una nueva pareja formada en *East Fork* 3. Aunque cinco pichones nacieron de ocho huevos fértiles, solamente hubo éxito de anidamiento en *East Fork* 3, donde volaron dos pichones en agosto, mucho más tarde que en años anteriores. El nido de *South Fork* 2 fracasó luego que desapareció la hembra, posiblemente depredada por un güaragüao. Se observó a dicha ave atacando en picada a la hembra antes de esta desaparecer y posteriormente se le observó intentando atacar al macho.

Esfuerzos de Recuperación

Existe coordinación inter-agencial para implementar medidas para aumentar la población de cotorras. El personal de tres agencias federales

continúa realizando censos para estimar la distribución y supervivencia de la población. F.J. Vilella y otros, diseñaron un escondite más crítico para la observación de las cotorras. También implementaron un método de censo poblacional usado al comienzo de la década del 1970 y descartado recientemente (basado en conteos al atardecer y al amanecer por el mismo observador en la misma área) para incrementar la precisión de los conteos. El Servicio de Pesca y Vida Silvestre utilizó observadores de nidos para mejorar la probabilidad de éxitos reproductivos en cada nido durante la temporada reproductiva del 1990. Para aumentar las comunicaciones inter-agenciales y ampliar el conocimiento público en general y el aprecio por la cotorra, T. Sorenson está comenzando un boletín sobre la cotorra, el cual estará en circulación en la primavera del 1991. Luego del Huracán Hugo, biólogos de vida silvestre del Bosque Nacional del Caribe reconstruyeron o repararon 4 nidos naturales de cotorra, 12 nidos artificiales para cotorras, 25 torres de observación, 8 escondites y 24 cajas para nidos del zorzal pardo. También, repararon y mejoraron 13 km de veredas.

Futuro de la Cotorra

Al presente, se están llevando a cabo investigaciones y actividades de manejo que le dan esperanza al futuro de la Cotorra de Puerto Rico. Kelly Brock conduce una investigación sobre la genética de la cotorra, con el fín de determinar linajes filogenéticos (relación) y los peligrosos efectos del apareamiento interno en un esfuerzo para mejorar su potencial reproductivo y supervivencia. Marsha Wilson y su equipo, conducen estudios de vocalización para determinar si cada cotorra puede reconocerse por su canto. Esto marca el comienzo a su vez de estudios para determinar los mejores métodos en la identificación de individuos en vuelo, estudios en territorios de las parejas de cotorras y eventualmente poder iniciar un estudio sobre la ecología de forrajeo de la cotorra. Juan Torres está estudiando las dinámicas en la formación de cavidades en los árboles donde la cotorra anida tradicionalmente. Joseph Wunderle continua estudios de fenología de frutas en las especies de árboles más importantes del bosque, muchos de los cuales son utilizados por las cotorras. Su investigación podría determinar patrones de producción de frutas (y por tanto, la disponibilidad de alimento para la cotorra) y reacciones de los árboles (ej., estrategias de regeneración y períodos de encrudecimiento) a disturbios, tanto naturales como inducidos por el ser humano.

En la población cautiva, las nuevas jaulas diseñadas por T. Sorenson han demostrado un gran potencial para fortalecer la unión entre las parejas y el éxito reproductivo en las cotorras cautivas, mientras que el nuevo aviario establecido en Río Abajo facilitará la re-introducción de cotorras producidas en cautiverio a las áreas tradicionales. La importancia de tener poblaciones de cotorras geográficamente separadas se hace evidente luego de ver la destrucción causada por el Huracán Hugo al hábitat y a las cotorras en la Sierra de Luquillo.

INVESTIGACIONES EN VIDA SILVESTRE

Juan A. Torres
Biólogo de Vida Silvestre

Durante el pasado año realizé investigaciones sobre el impacto del Huracán Hugo en los insectos, revisé la literatura en entomología forestal en la Sierra de Luquillo y publiqué un artículo sobre la hormiga brava *Solenopsis invicta* (Torres 1990).

Influencia del Huracán Hugo sobre Insectos

El Huracán Hugo atacó la parte noreste de Puerto Rico el 18 de septiembre de 1989. Los vientos máximos del huracán fueron aproximadamente 225 km/hr. Estos vientos soplaron por alrededor de 18 horas en las montañas de la Sierra de Luquillo causando daño extenso en la vegetación de las zonas bajas. Luego del huracán, una invasión extensa de plantas oportunistas ocurrió en el bosque.

En octubre aumentaron los dípteros, especialmente las moscas fruteras. Esto fue, probablemente, como consecuencia del aumento en frutas podridas, aunque no se puede descartar la posibilidad de que haya ocurrido desplazamiento vertical de las moscas. Los árboles dañados y la madera muerta fue atacada por descortezadores de madera (Scolytidae) y escarabajos de la familia Platypodidae con gran fortaleza durante los meses de noviembre y diciembre.

Las más grandes explosiones poblacionales de insectos ocurrieron durante la primavera y principios de verano (abril-junio 1990). Quince especies de Lepidoptera sufrieron explosiones poblacionales. Todas las Lepidopteras se alimentaron de la vegetación oportunista que penetró al bosque luego del huracán. La explosión poblacional más espectacular fue la de *Spodoptera eridania* (Noctuidae). Esta alevilla se alimentó de 56 especies de plantas pertenecientes a 32 familias. El fín de la explosión poblacional de *S. eridania* estuvo relacionada con la eliminación de sus huéspedes preferidos y con un aumento en parasitismo por ichneumónidos (Hymenoptera). El parasitismo por tachinidos (Diptera) pudo haber contribuído a la reducción en la abundancia de las otras lepidópteras.

Entomología Forestal

Esta revisión se publicará como un reporte general técnico. Se dio énfasis a las investigaciones conducidas en el Bosque Experimental de Luquillo (Sierra de Luquillo). Provee una introducción a aquellos interesados en proseguir investigaciones en los insectos que habitan el Bosque Experimental de Luquillo y como una guía para identificar posibles plagas de insectos. La revisión consiste de cuatro partes. La primera trata sobre ecología básica, la segunda sobre plagas forestales de insectos, la tercera cubre los insectos que atacan la madera durante el secado y los insectos que se nutren de madera seca, y la sección de referencias consiste de una bibliografía anotada que incluye la sistemática y la taxonomía de diferentes órdenes de insectos en Puerto Rico.

Hormigas Bravas

La hormiga brava *Solenopsis invicta* invadió a Puerto Rico unos años atrás. Su presencia ha causado alarma entre el público y los agricultores. Revisé la ecología de esta especie en los Estados Unidos, Brasil y Puerto Rico. Mucha de la investigación realizada con esa hormiga es inadecuada para contestar preguntas sobre su efecto sobre la vida silvestre, el público y las cosechas. Esto se debe a la falta de controles experimentales apropiados o la falta de repeticiones de las unidades experimentales.

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MANEJO DE CUENCAS HIDROGRAFICAS

F.N. Scatena
Hidrólogo

Durante el 1990 la investigación de las cuencas se concentró en evaluar los impactos y la reconstrucción natural del Bosque de Bisley después que el Huracán Hugo pasara sobre esa área en septiembre de 1989. Además de los estudios longitudinales existentes, nuevos esfuerzos investigativos se iniciaron en la vegetación herbácea, fenología, microclima y plántulas. La primera tesis doctoral basada en el área de Bisley también se completó (Basnet 1990).

La resistencia del tabonuco (*Dacryodes excelsa*), el árbol dominante del bosque a los huracanes, fue ampliamente demostrada con el paso del Huracán Hugo (Basnet 1990, Koning 1990). Aunque casi cada árbol en el bosque sufrió daño de una forma u otra, el tabonuco fue la única especie que demostró una resistencia significativa a daños por el huracán (Basnet 1990). Los daños también variaron significativamente entre la clase diamétrica, los troncos >60 cm en diámetros recibieron el mayor daño. La intensidad del daño fue más significativa en los valles que en las cimas o pendientes.

Anterior al huracán, se observó toposequencias para la vegetación (Heaton y Letourneau 1989, Basnet 1990), *"throughfall"* y estructura de la arboleda (Scatena 1990a), suelo, y otros factores ecológicos. Las cimas estaban prácticamente dominadas por rodales de tabonuco mientras que las áreas ribereñas tenían vegetación de tipo sucesional (Heaton y Letourneau 1989, Scatena 1990b). La dinámica del área ribereña también parece importante al ciclo de nutrientes acuáticos (Bowden et al. 1990), el insumo de maderas a los canales de riachuelos (Covich y Crowl 1990) y al manejo de alcantarillados y otras estructuras de canales (Scatena 1990c).

Un año después del huracán, 45% de las cuencas estaban cubiertas por vegetación herbácea (Chinea 1990). Un total de 41 especies herbáceas fueron identificadas y la composición era más diversa que las previamente informadas en un bosque cerrado.

Análisis de componentes principales indican que la heterogeneidad en regímenes de luz responde a alguna de la diferenciación en la comunidad herbácea. El tamaño de la población de plántulas del árbol invasor exótico, *Albizia procera,* también correlaciona significativamente con la condición de luz (Chinea 1990b).

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